

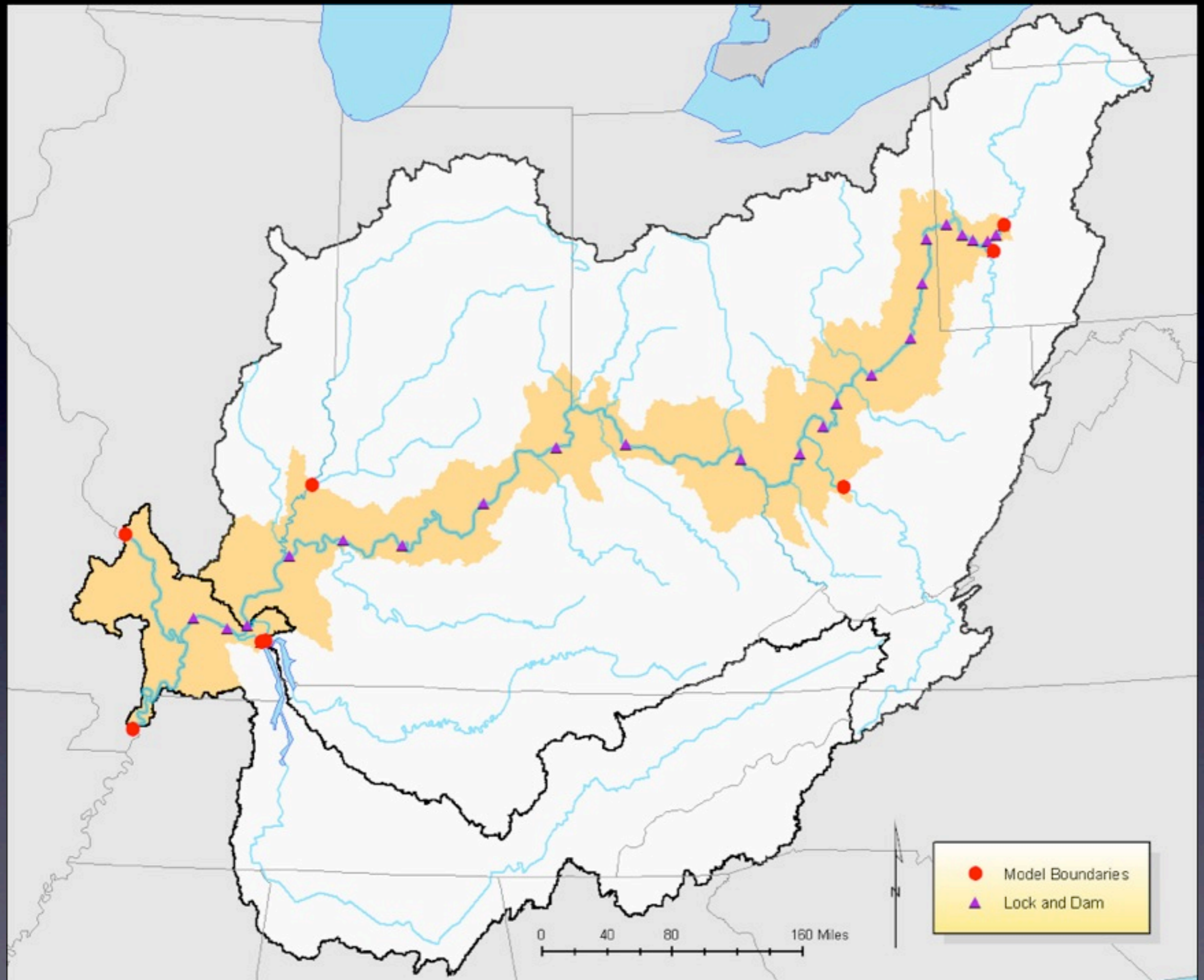
# Ohio River Community HEC-RAS Model

Thomas Adams, NWS/OHRFC

[thomas.adams@noaa.gov](mailto:thomas.adams@noaa.gov)

# Model Goals

- Develop a HEC-RAS model that will improve forecasts for the Ohio River mainstem & major tributaries using an **Unsteady Hydraulic Flow Model**:
  - Stage
  - Flow
  - Velocity
- Create a HEC-RAS model that will serve NWS & USACE operational needs.
- Use the best available data at the time of model development and enhance the model as higher quality data becomes available
- Provide better visualization of data during flood events on the Ohio River.
- Provide Real-Time Flood Inundation Mapping.
- Prepare for Community Hydrologic Prediction System - Flood Early Warning System (CHPS-FEWS) — NWSRFS replacement



# Allegheny River Upstream Boundary

Natrona L&D

F



# Monongahela River Upstream Boundary

Braddock Dam

F

Monongahela River – 11.01 river miles from the confluence (downstream of Braddock L&D). This is a daily forecast point, and is a reliable and stable flow point which will provide information to forecast stages and flows at Pittsburgh.

# Mississippi River Upstream Boundary



Mississippi River – 110.4 river miles upstream from the Ohio/Mississippi confluence (at Chester, IL gage). This is a daily forecast point where the NCRFC provides the LMRFC Mississippi River flows. This is also a stable river reach.

Chester

# Mississippi River Downstream Boundary

Concord



Mississippi River – 106.62 river miles downstream from the Ohio/Mississippi confluence (at the Caruthersville, MO gage.) This will eliminate the effects of the boundary condition for the forecast location of the Cairo gage. It is also the downstream point for the Corps Cascade Model

Caruthersville

Caruthersville, MO

# The Model

- Joint development effort by the NWS/OHRFC and USACE Great Lakes & Ohio River Division, with USGS cooperation
- ~3-year development effort
- Mississippi R to above Pittsburgh on the Allegheny (Natrona L&D, PA) & Monongahela (Braddock L&D, PA) Rivers
- Model to the 500-yr floodplain limits
- Lock & Dam operations are modeled
- Unsteady flow model
  - 15-min time step
- Real-time operations
- Same model used at both the OHRFC and USACE
- Model changes will be synchronized
- Detailed review by the USACE HEC, Davis, CA

# Data types and sources

Data Type

Data Source

**Surveyed Cross Sections**

Corps Pittsburgh District  
Corps Louisville District  
Corps St. Louis District  
Corps Memphis District

**National Elevation Datasets (NED)**  
(10 m and 3 m)

US Geological Survey

**Lidar Data**

Corps Memphis District,  
PASDA, OGRIP, other agencies

**Bathymetry Data** (Meldahl Dam to Cincinnati)  
(Cairo to Carruthersville)

USGS, Ohio District,  
Corps, Memphis District

**National Hydrography Dataset (NHD)**

USGS

**Real-time Stream Flows**

NWS/OHRFC, USGS, & USACE

**Stream flow forecasts**

NWS



# Datums

**Horizontal datum — NAD83**

**Vertical Datum — NAVD88**

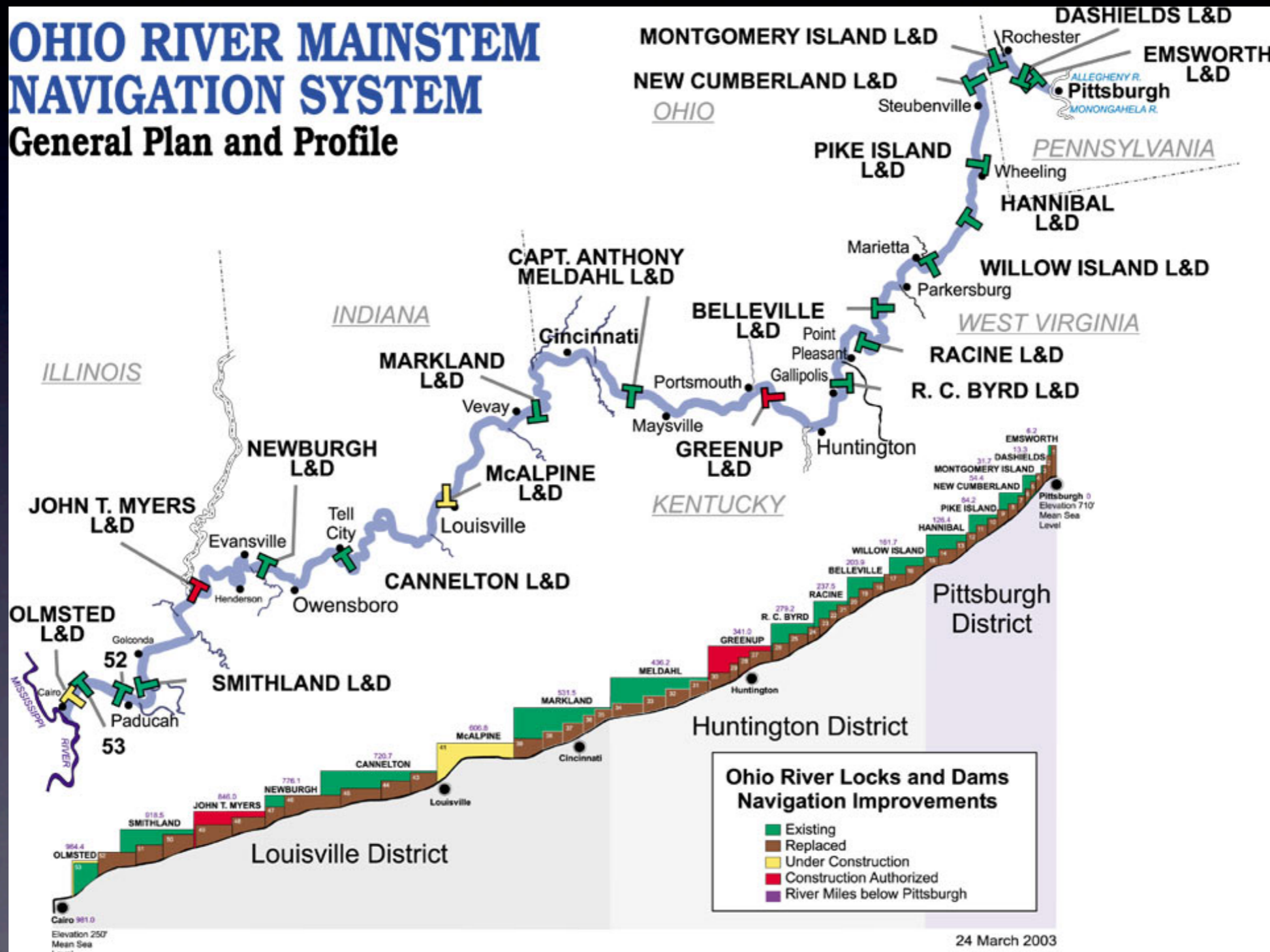
**Albers (equal area) projection in *feet***



# Modeling Challenges

- Channel data, etc. generated from 1930s to 2005
- Data formats - HEC-2, XYZ, Digitized
- Data merging (over banks and channel data)
- Geo-referencing (DEM, datum, river centerline, banks, flow paths, and cross sections.
- Large quantity: over 3500 cross sections processed
- Lock and Dam operations
- Flow data and local inflow issues — no direct Ohio R. flow measurements
- Biggest HEC-RAS implementation ever
- No direct funding except USACE funds for HEC support for model review

# Ohio River Locks & Dams



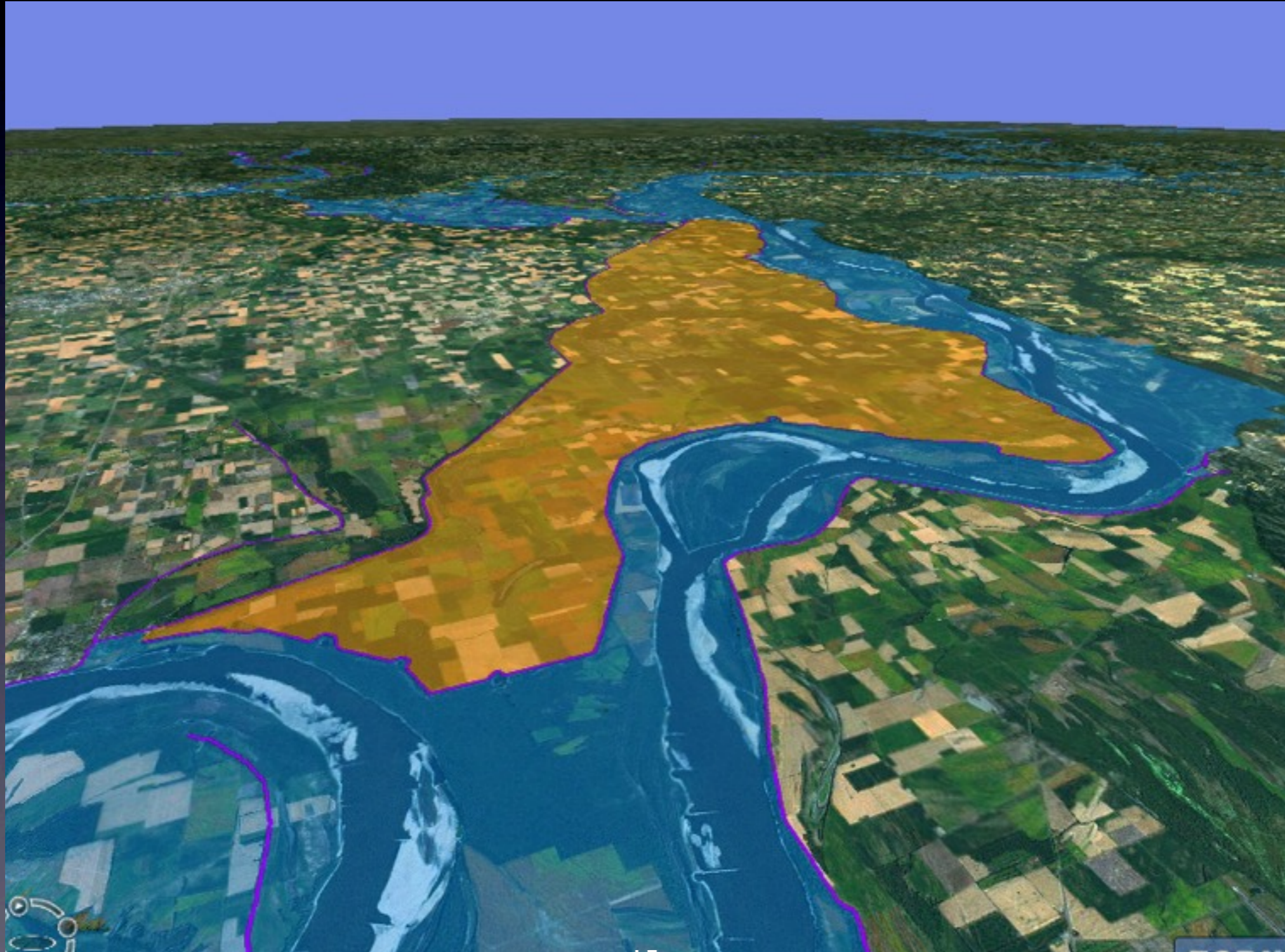
# Status

- 1457.5 miles modeled
- Total cross-sections — ~3500
- 24 Locks & Dams
  - Ohio River — 22
  - Kanawha River — 2
- 26 bridges
- 43 storage areas
- Over 54 lateral structures (levees, etc...)

# March 1997 Flood Inundation Area HEC-RAS Model Run



# March 1997 Flood — Birds Point/New Madrid Floodway



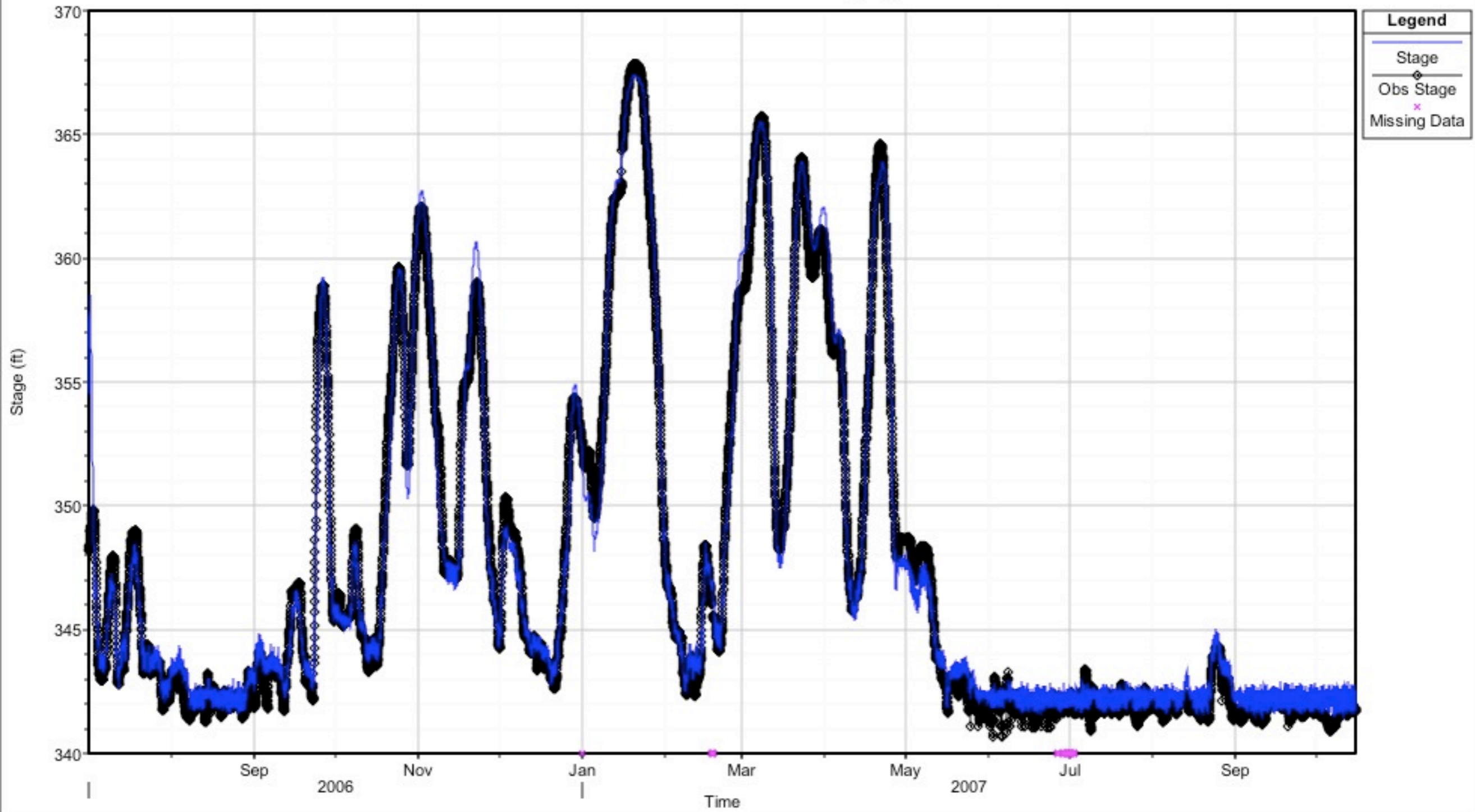


Caruthersville, MO

# “The Point” — Pittsburgh, PA remnants of Hurricane Ivan



Plan: OHS River: Ohio River Reach: SOHS\_Upper RS: -790.9

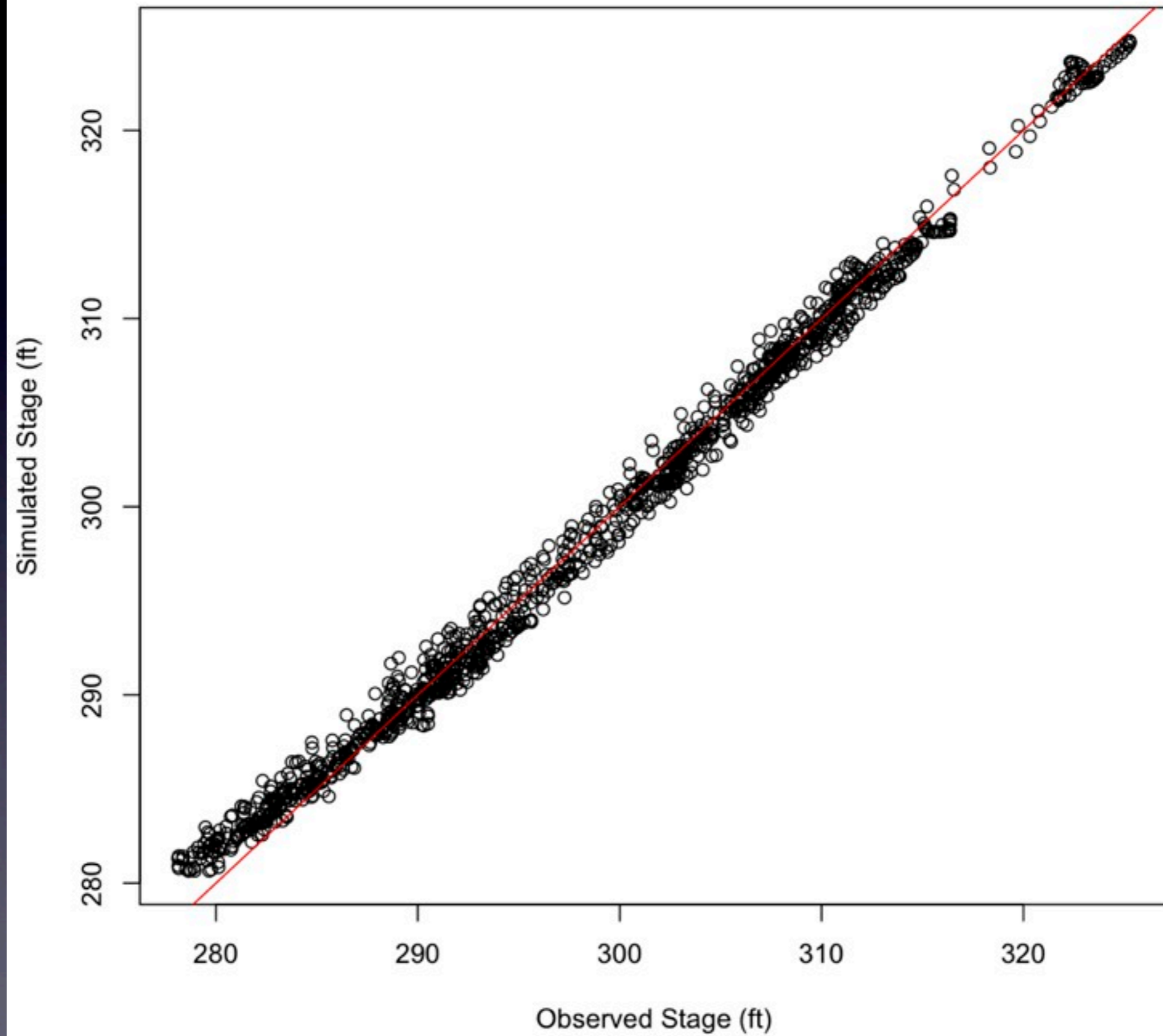


# Calibration Statistics

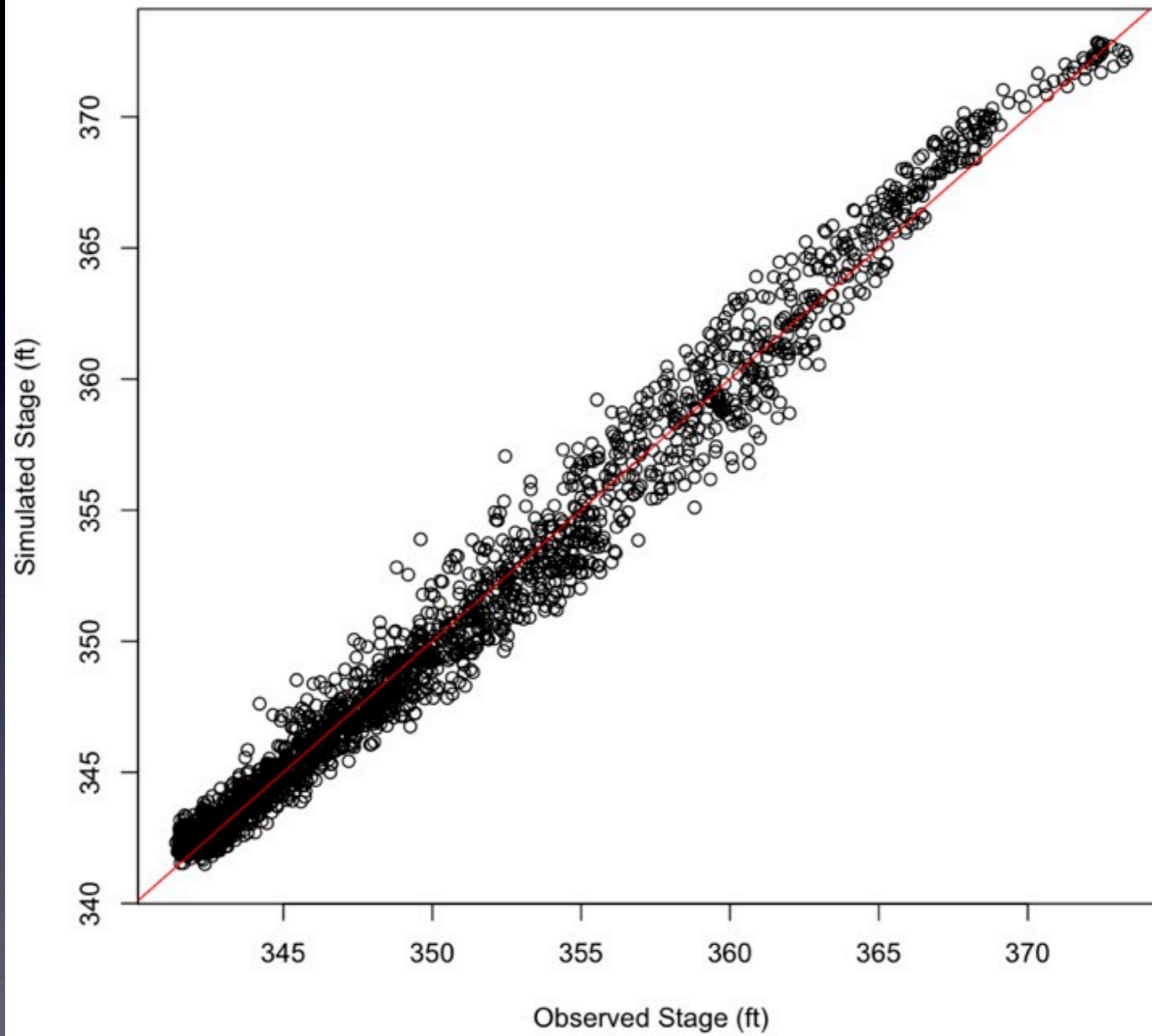
(~12 months ago)

Location	MAE	ME	MSE	R <sup>2</sup>
Pittsburgh, PA (PTTP1)	0.2096	-0.0180	0.0847	0.8585
Evansville, IN (EVVI3)	0.7365	0.0587	0.9830	0.9842
Cairo, IL	0.8253	0.0277	1.0830	0.9935
Chester, IL	0.3677	0.1516	0.3269	0.9960
Caruthersville, MO	0.8634	0.2003	1.3260	0.9887

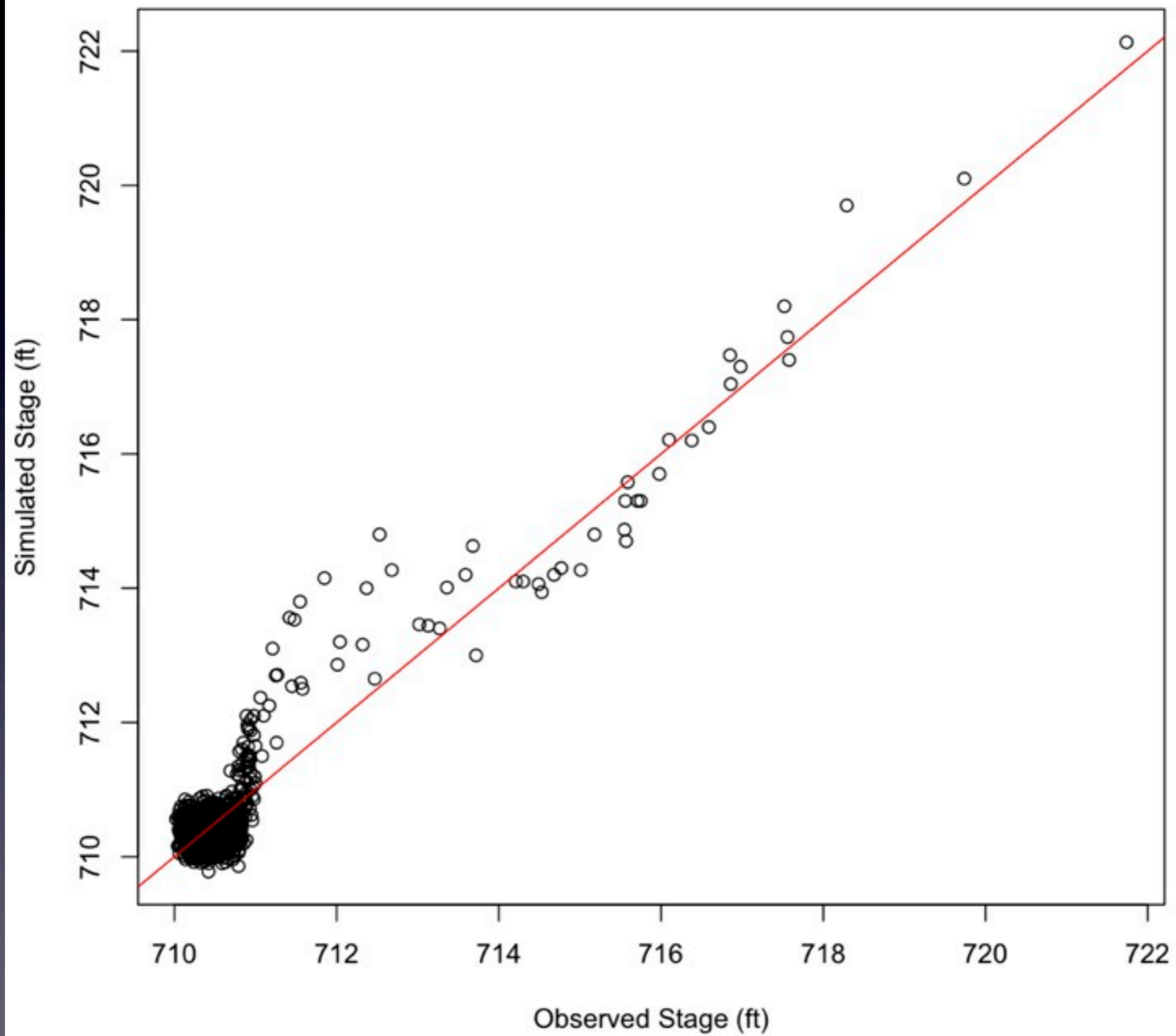
# Cairo



# EVVI3



# PTTP1

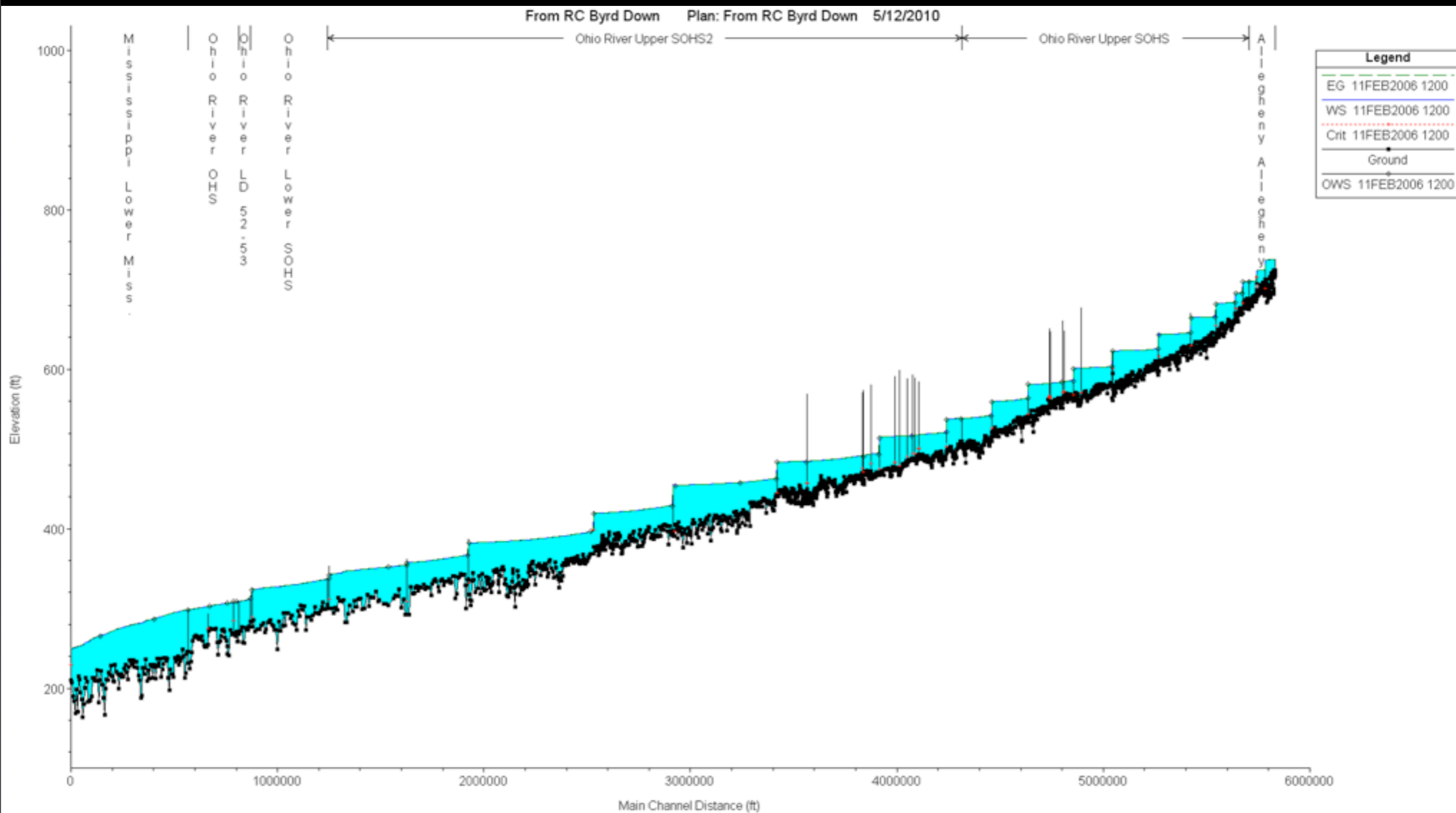


# Near-term Plans

- Model calibrations completed for phase I
- Soon will add:
  - Kentucky R
  - Cumberland R
  - Miami R
- Real-time operational testing will begin soon — implementation first on a standalone PC running MS-Windows
- Migration to Linux on CHPS-FEWS by December 2010
- Freely available by request through OHRFC website
  - secure ftp download
  - Agreement to *Copyleft* (similar to *Gnu Public license*)

# Natrona, PA to Caruthersville, MO

## 11 Feb. 2006 - 27 Feb. 2010



# Acknowledgments

Sherry Chen, NWS/OHRFC

Ray Davis, NWS/OHRFC

Joe Heim, NWS/OHRFC

Trent Schade, USACE/LRD

Debbie Lee, USACE/LRD

# Thank you...

## Questions?

[www.erh.noaa.gov/er/ohrfc/](http://www.erh.noaa.gov/er/ohrfc/)

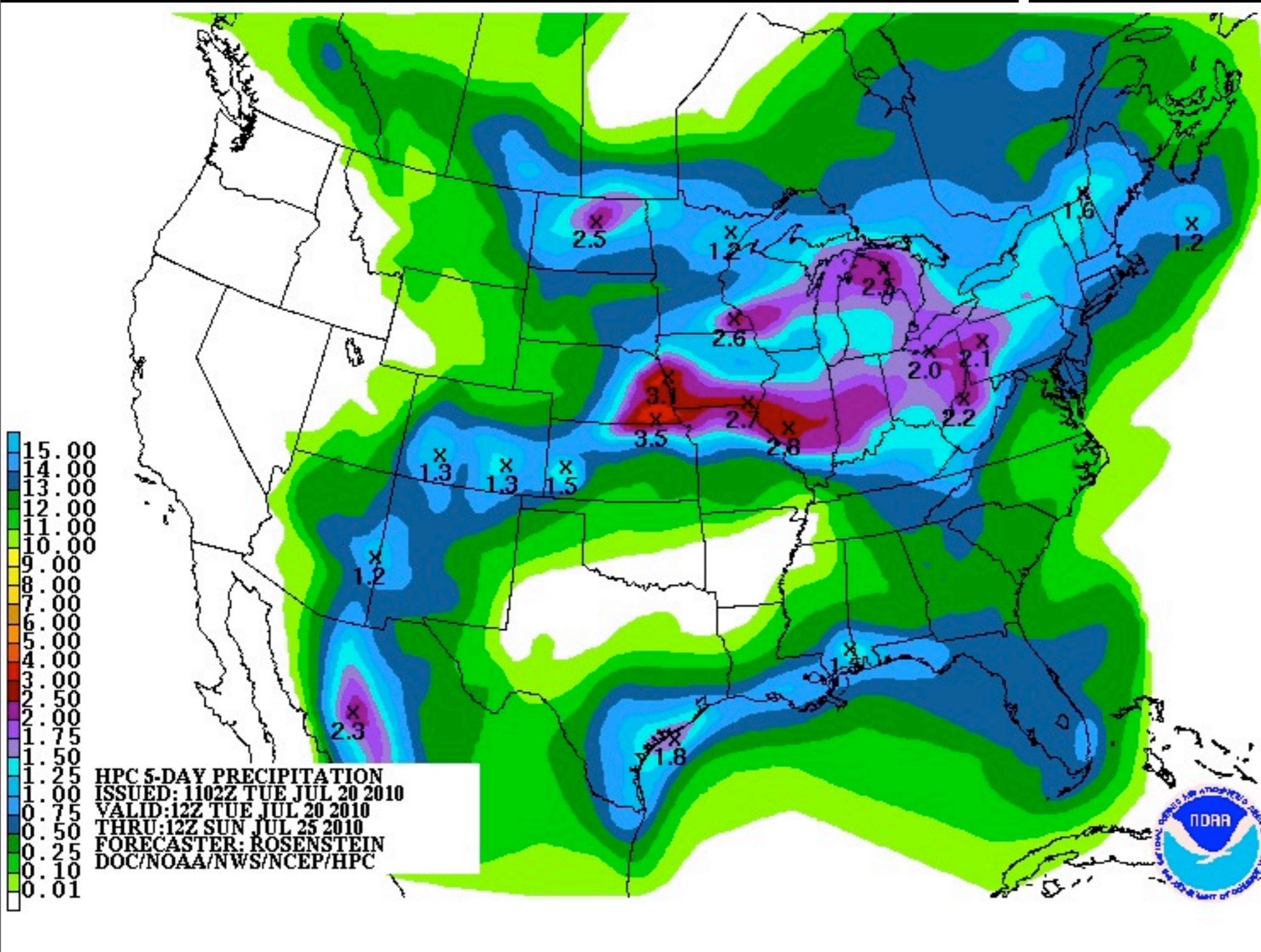
# Meteorological Model based Ensemble Forecast System — MMEFS

The generation of Short Lead-time Hydrologic Ensembles from Numerical Weather  
Prediction Model Ensembles

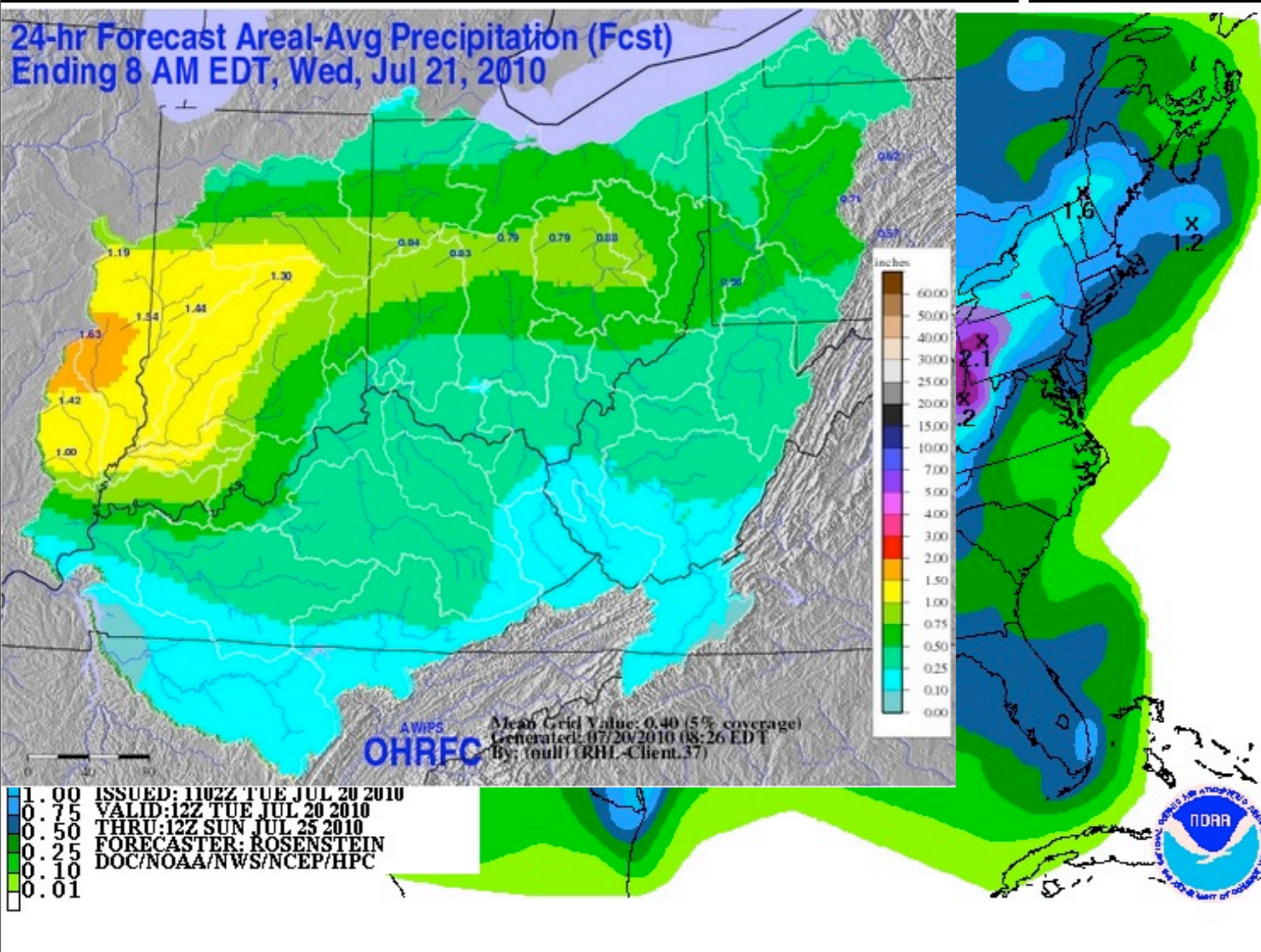
Thomas Adams NWS/OHRFC  
*thomas.adams@noaa.gov*

One of the *BIG* problems

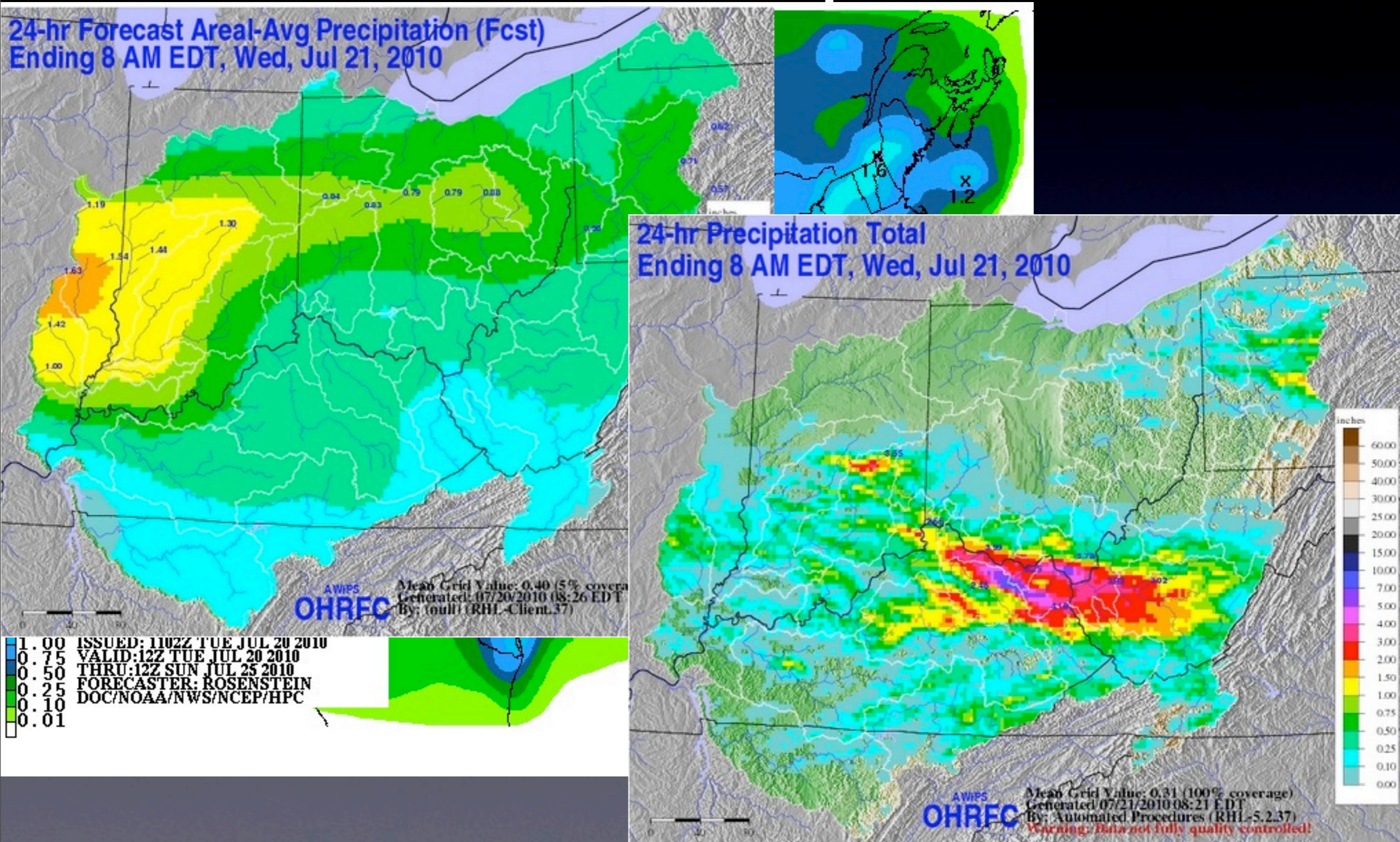
# One of the *BIG* problems



# One of the *BIG* problems



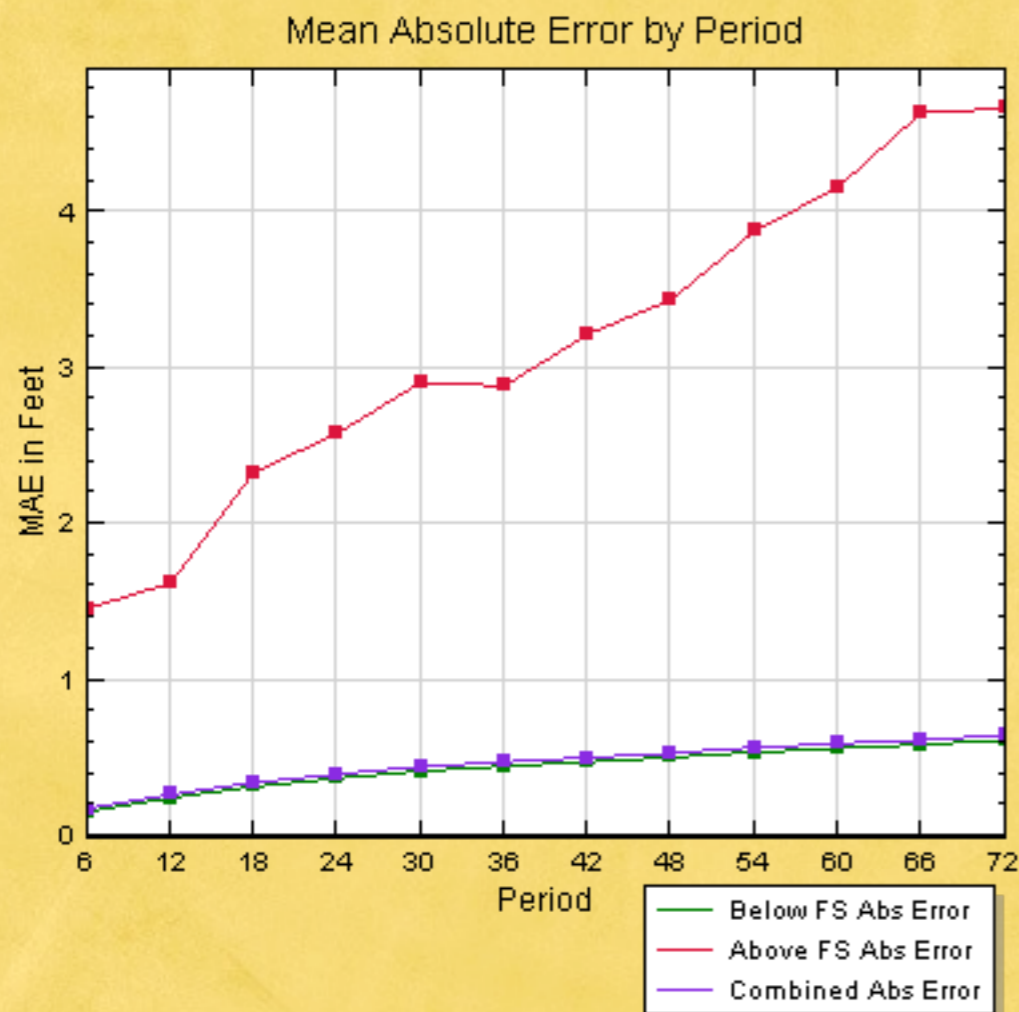
# One of the *BIG* problems



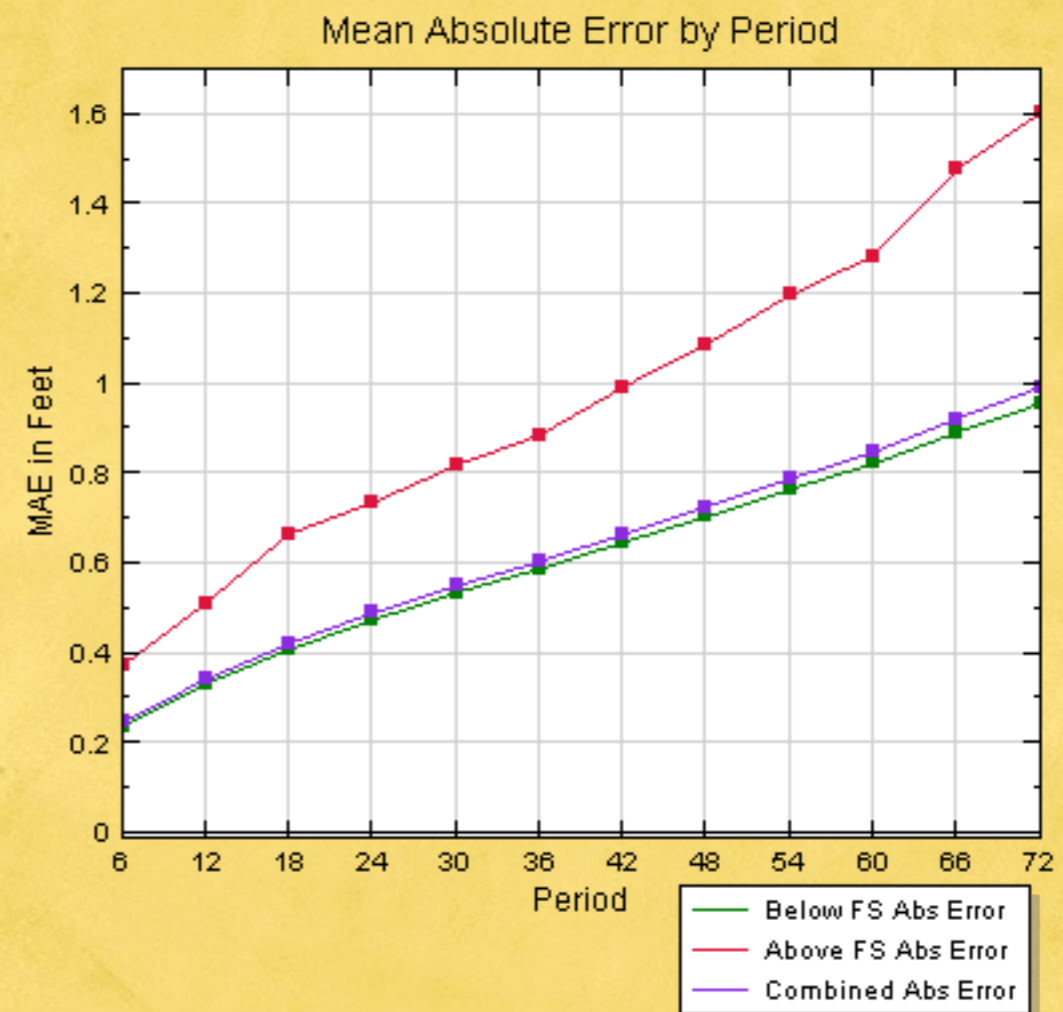
# What are we trying to do?

# OHRFC stage verification 04/2001-05/2010

## Fast



## Slow



$$\frac{1}{n} \sum_{i=1}^n |p_i - o_i|$$

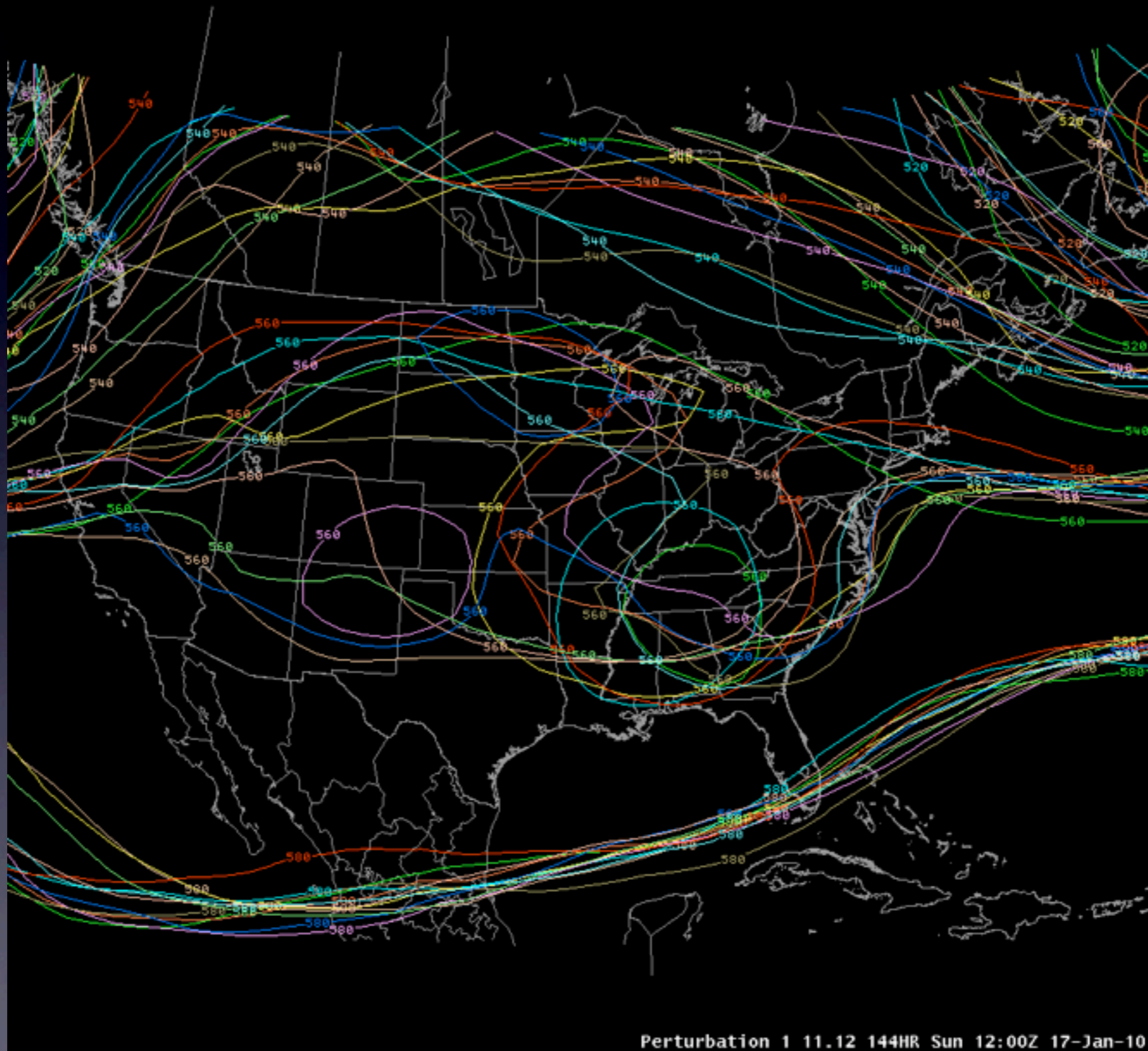
# Short Lead-time Ensemble Hydrologic Forecasting

- Errors in predicting precipitation (in particular), temperature, & other meteorological variables... leads to hydrologic forecast uncertainty
- The hydrologic forecast uncertainty must be quantified and passed on to the public & decision makers
- Use NWP & hydrologic models to objectively quantify forecast uncertainty

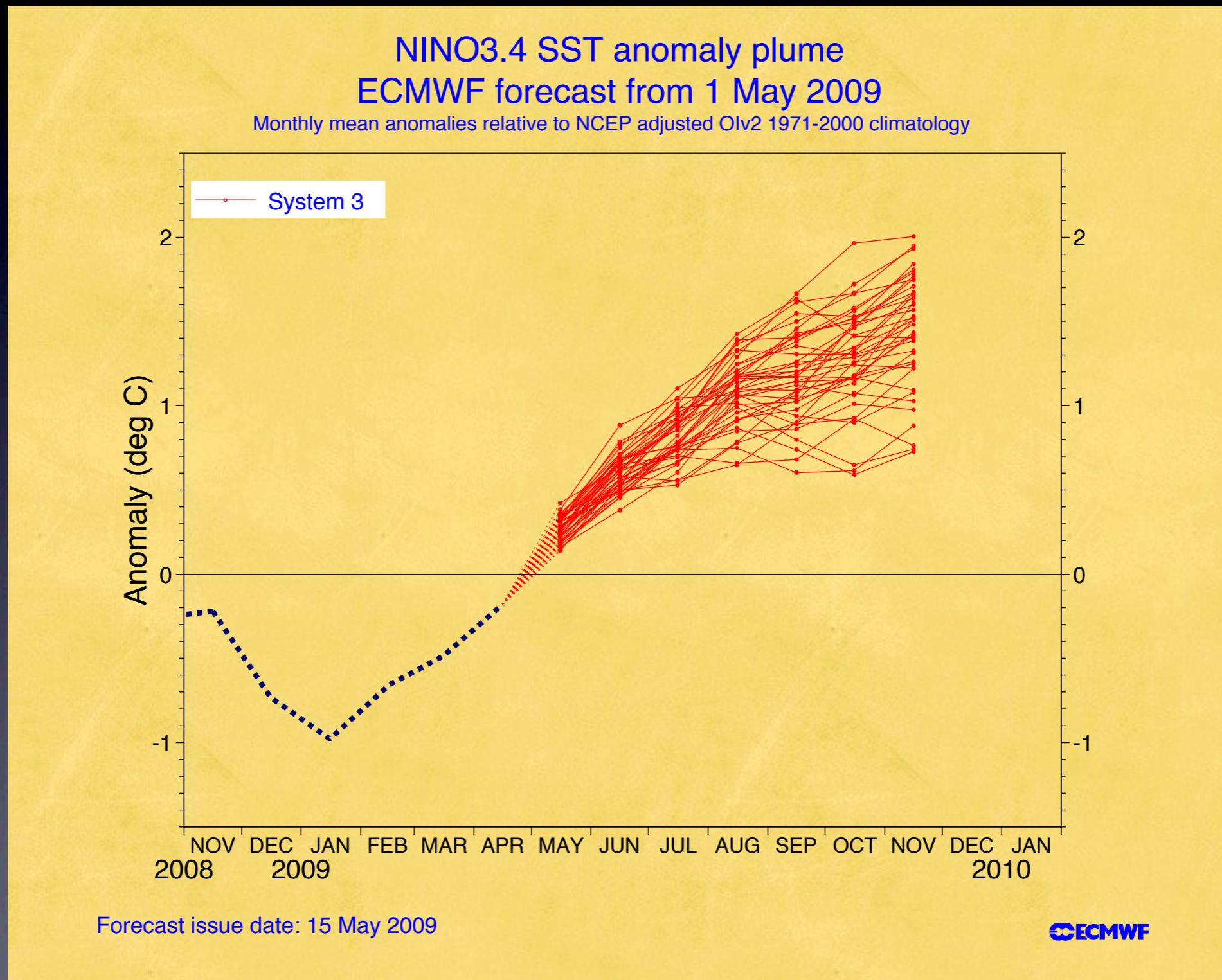
# Short lead-time probabilistic streamflow forecasting

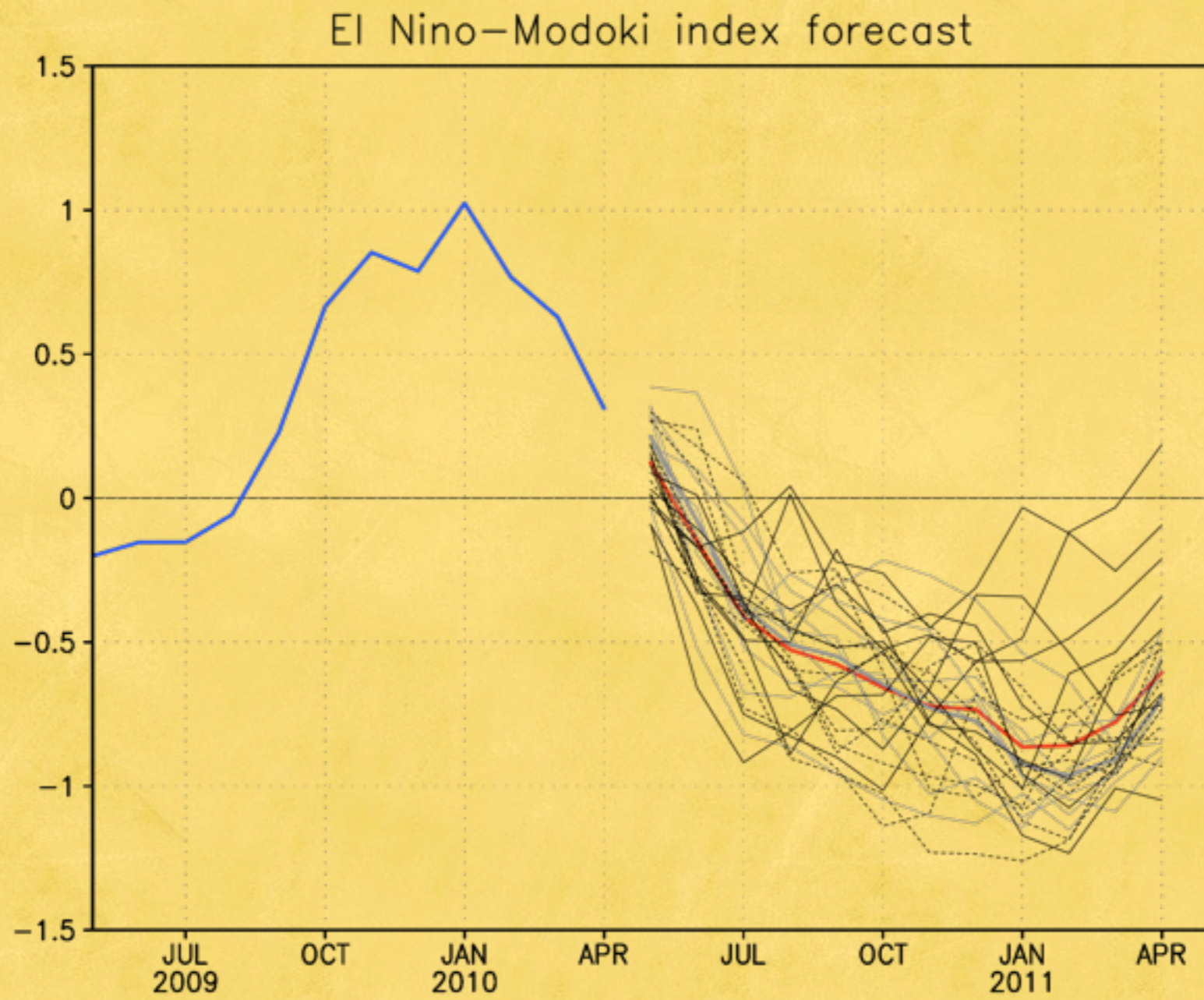
- Goal is to generate short lead-time (Days 1 to 7) probabilistic hydrologic forecasts — focused on *flood forecasting*
- Cooperative project with the NERFC & MARFC, with assistance from the NWS/National Centers for Environmental Prediction (NCEP)
- SERFC is working on implementing the MMEFS

# GEFSA Ensembles

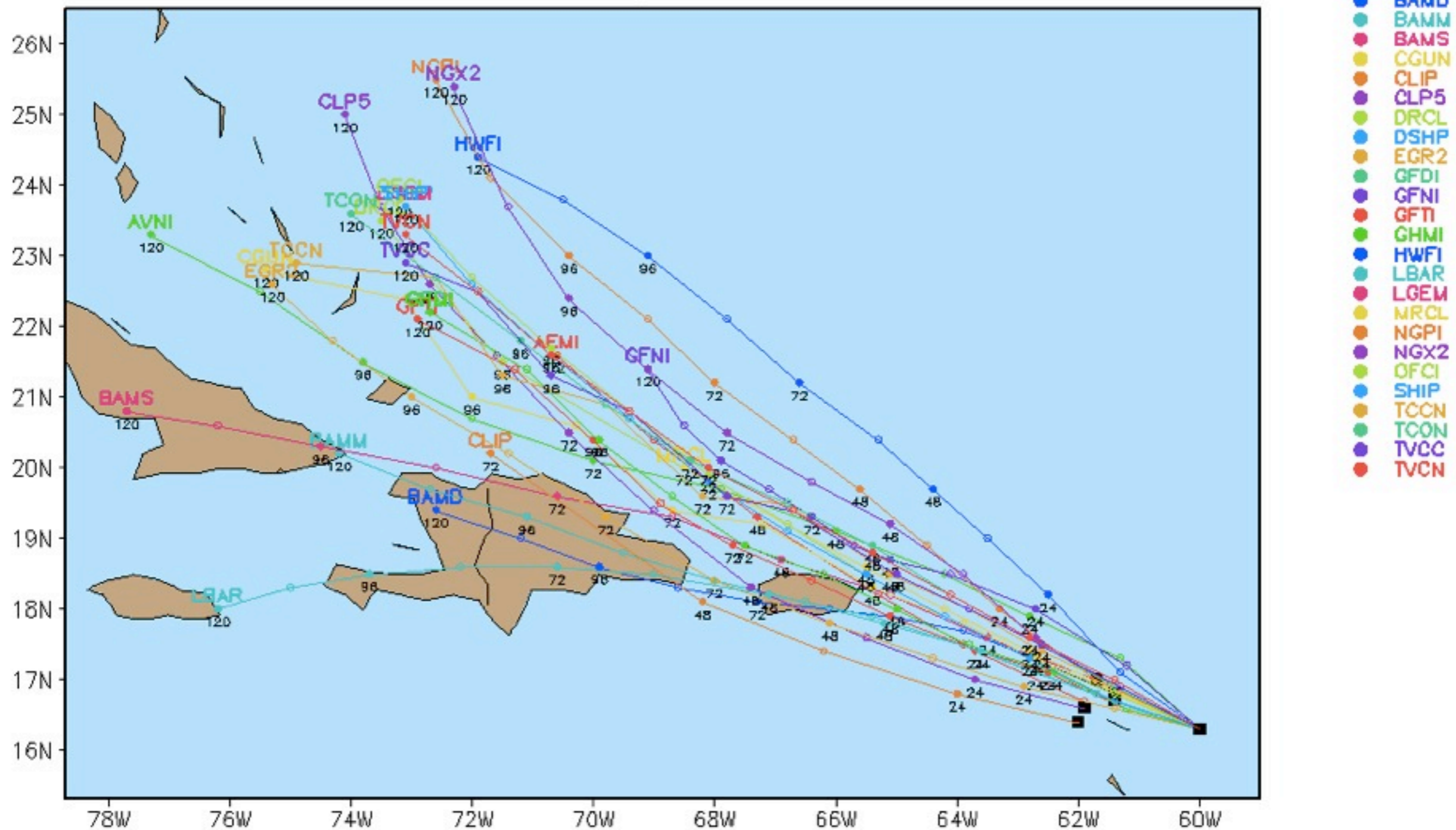


# ECMWF NINO3.4 SST anomaly plume





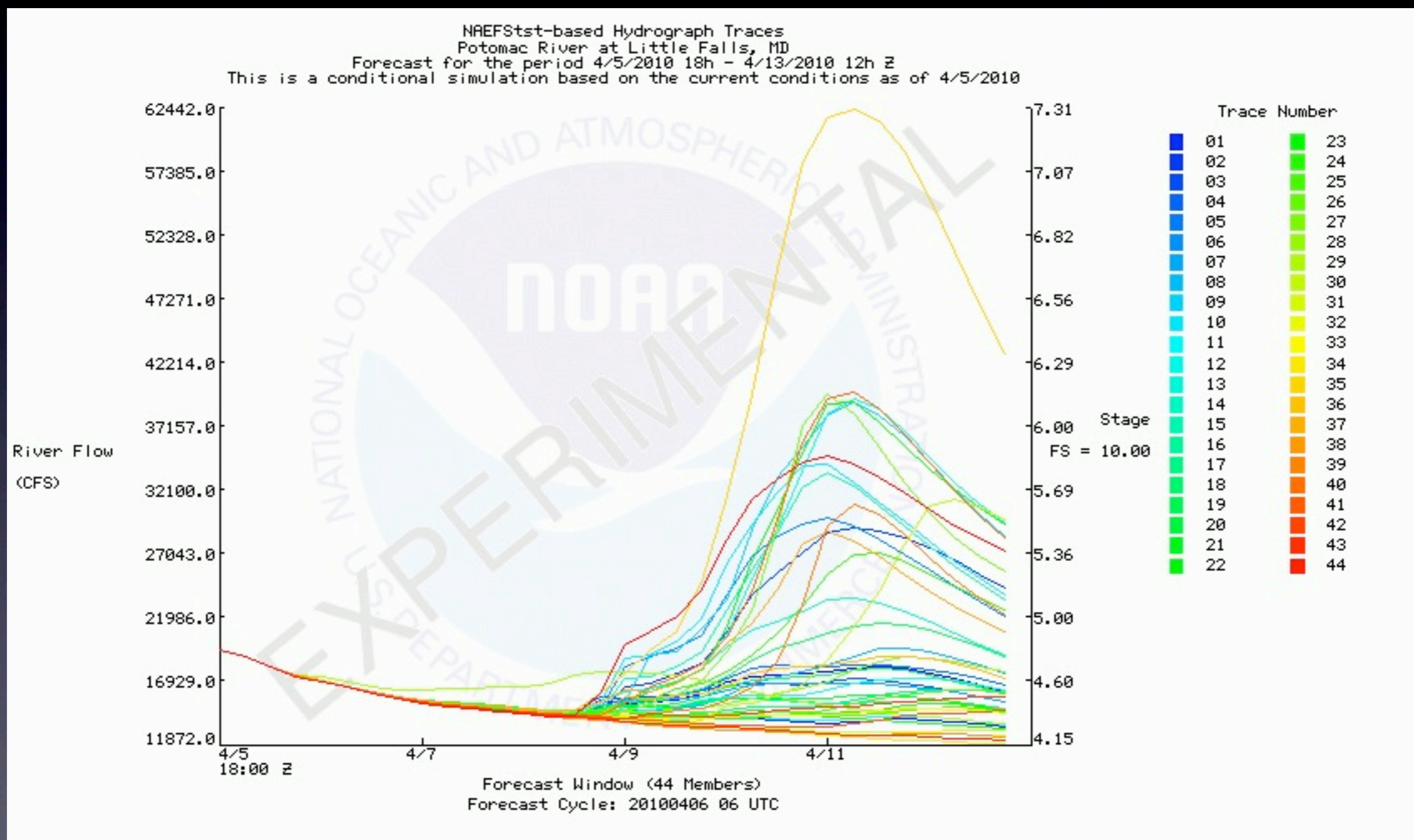
# Atlantic TROPICAL STORM ERIKA Model Tracks 12Z 02 September 2009



Tropical Cyclone Model Plots  
<http://moe.met.fau.edu/~acevans/models/>  
 Redistribution of these images is prohibited.

DISCLAIMER: Do not use this image in place of official sources.  
 The official NHC forecast is always available at <http://www.nhc.noaa.gov>.  
 Forecast points above are shown in 12 hr increments. Initial points denoted by black squares.

# MMEFS NAEFS ESP ensemble traces

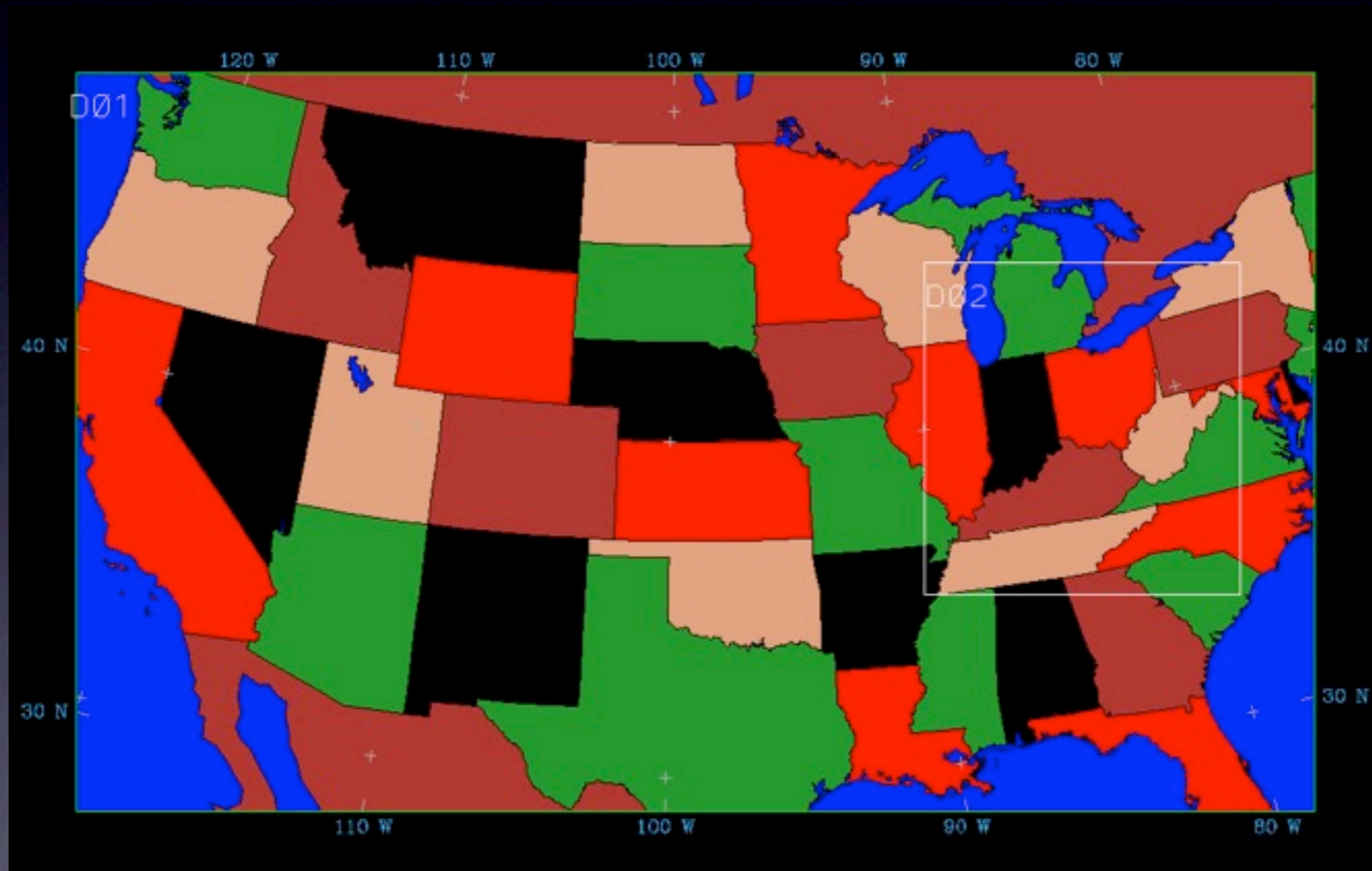


# Sources of Forecast Error

# Sources of Forecast Error (in order of importance)

- Precipitation forecast (QPF)
- Precipitation Estimation (QPE)
- Precipitation typing (rain/snow/ice/freezing rain)
- Temperature estimation (higher elevations, affecting snowmelt rates)
- Model error
  - Channel routing
  - Hydrologic
  - Snowmelt
  - Reservoir
- Evapotranspiration estimation
- Forecaster error

# OHRFC Mesoscale NWP Modeling



# Example 24-hr rainfall ending 07/28/2006-12Z

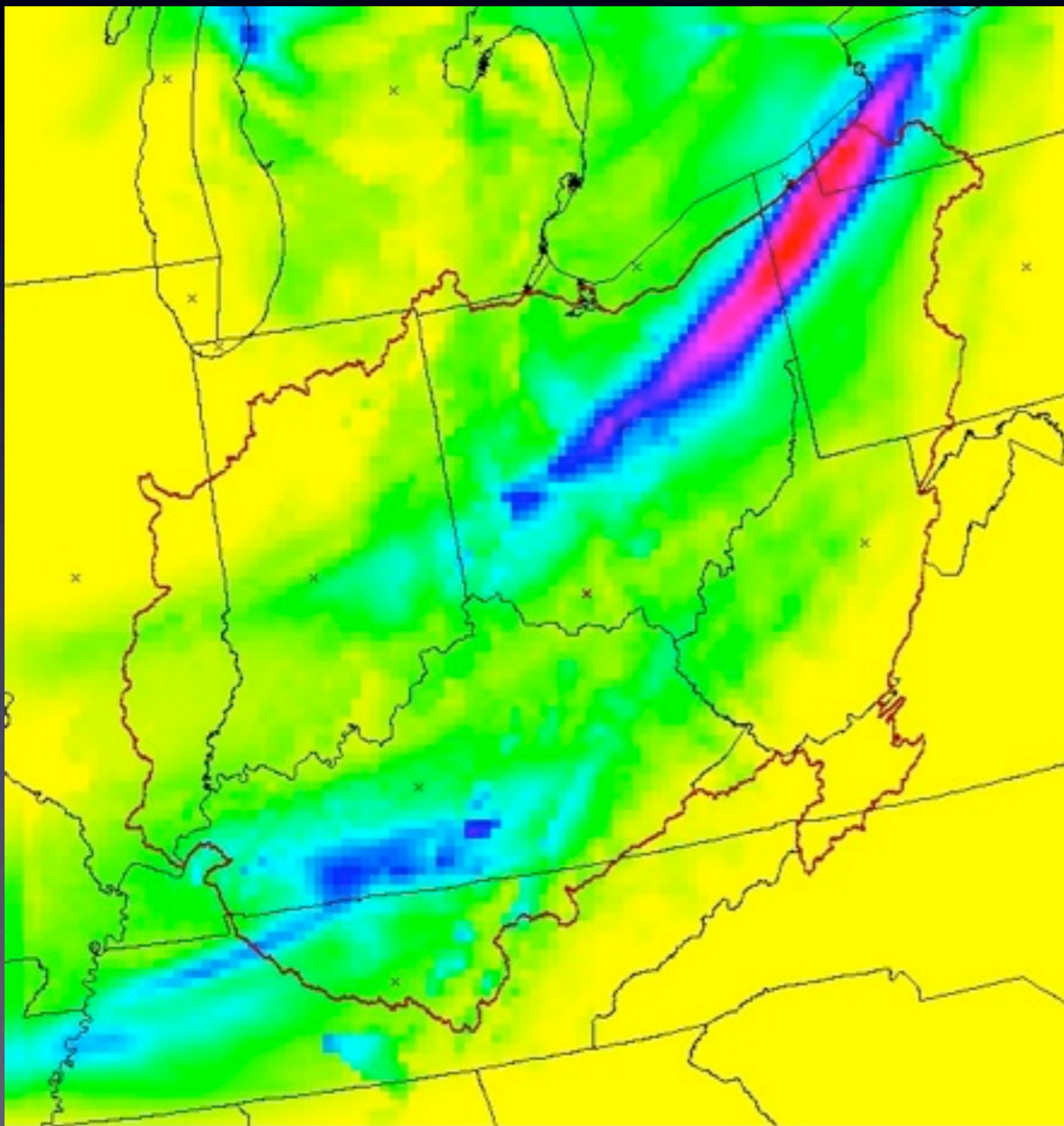
MM5 model

Observed

# Example 24-hr rainfall ending 07/28/2006-12Z

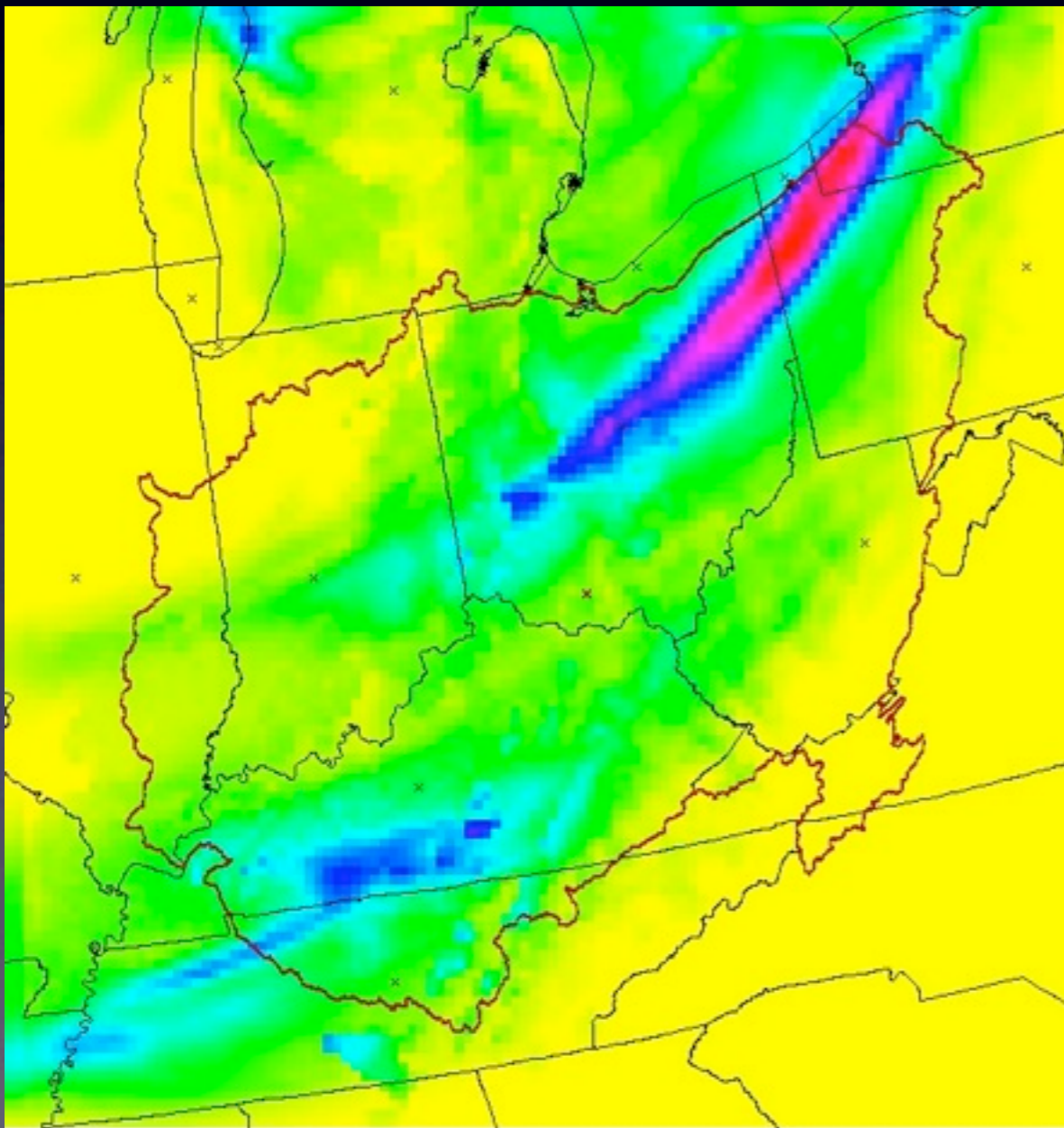
MM5 model

Observed

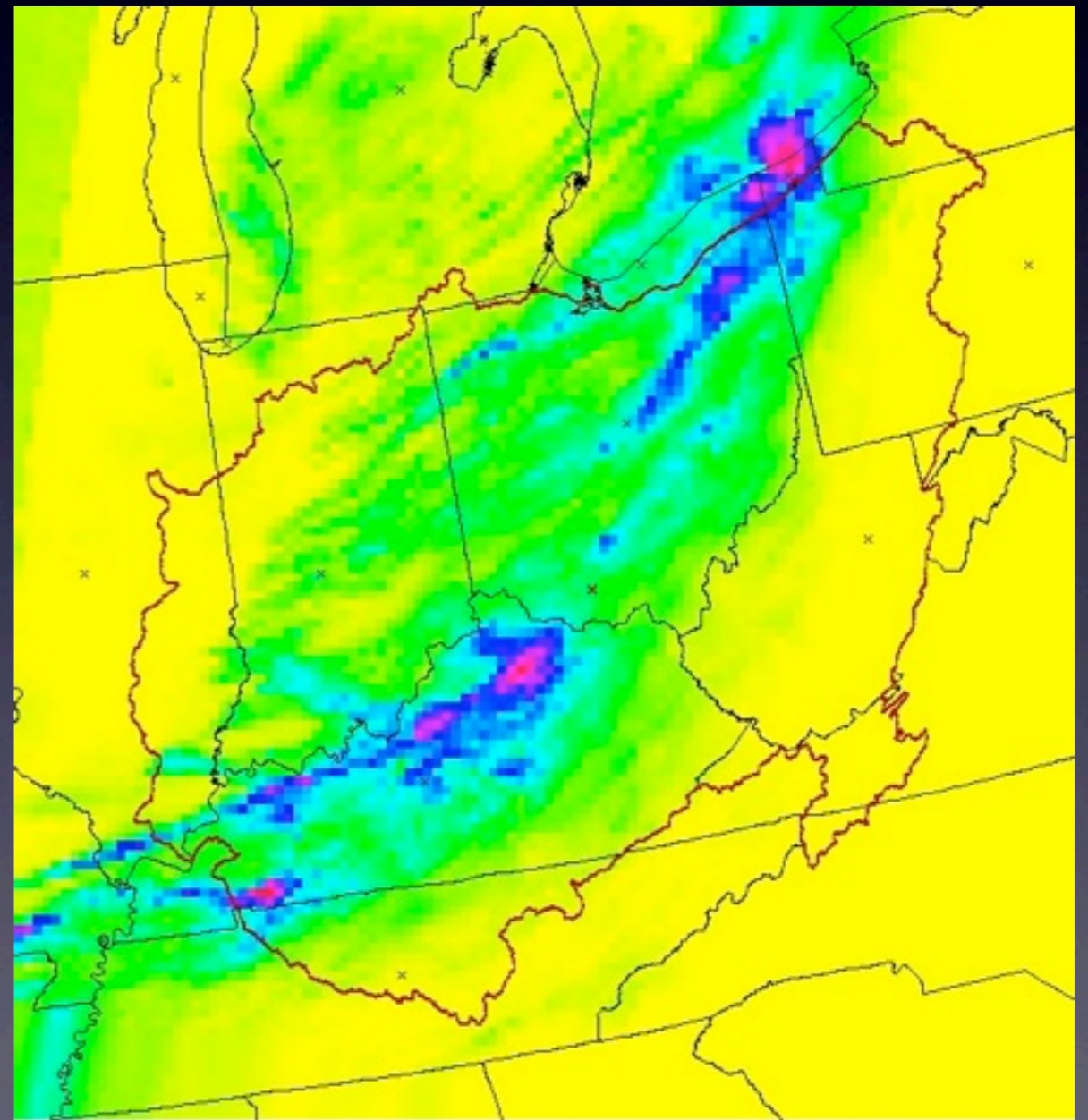


# Example 24-hr rainfall ending 07/28/2006-12Z

MM5 model



Observed



# Example 24-hr rainfall ending 11/17/2006-12Z

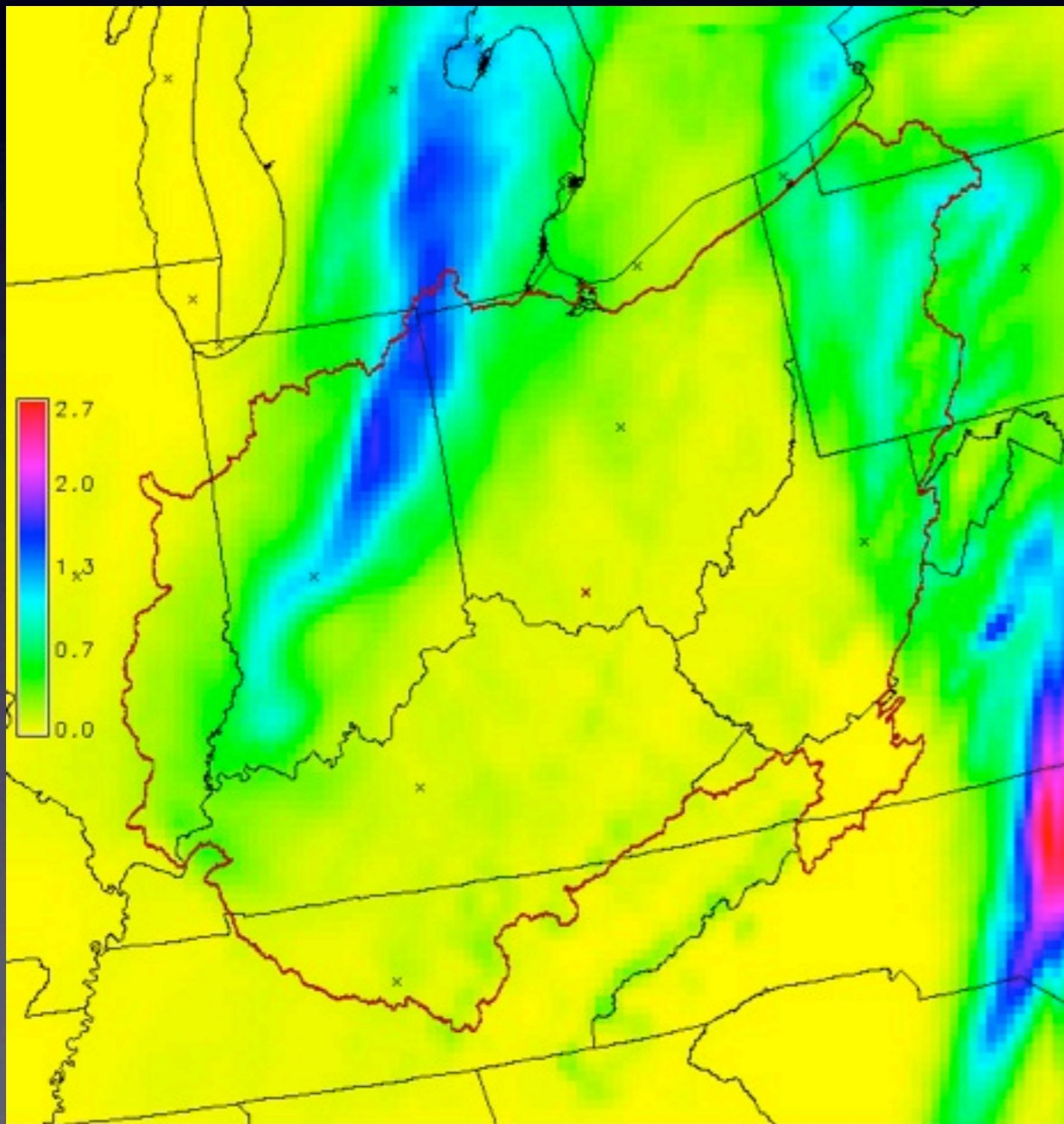
MM5 model

Observed

# Example 24-hr rainfall ending 11/17/2006-12Z

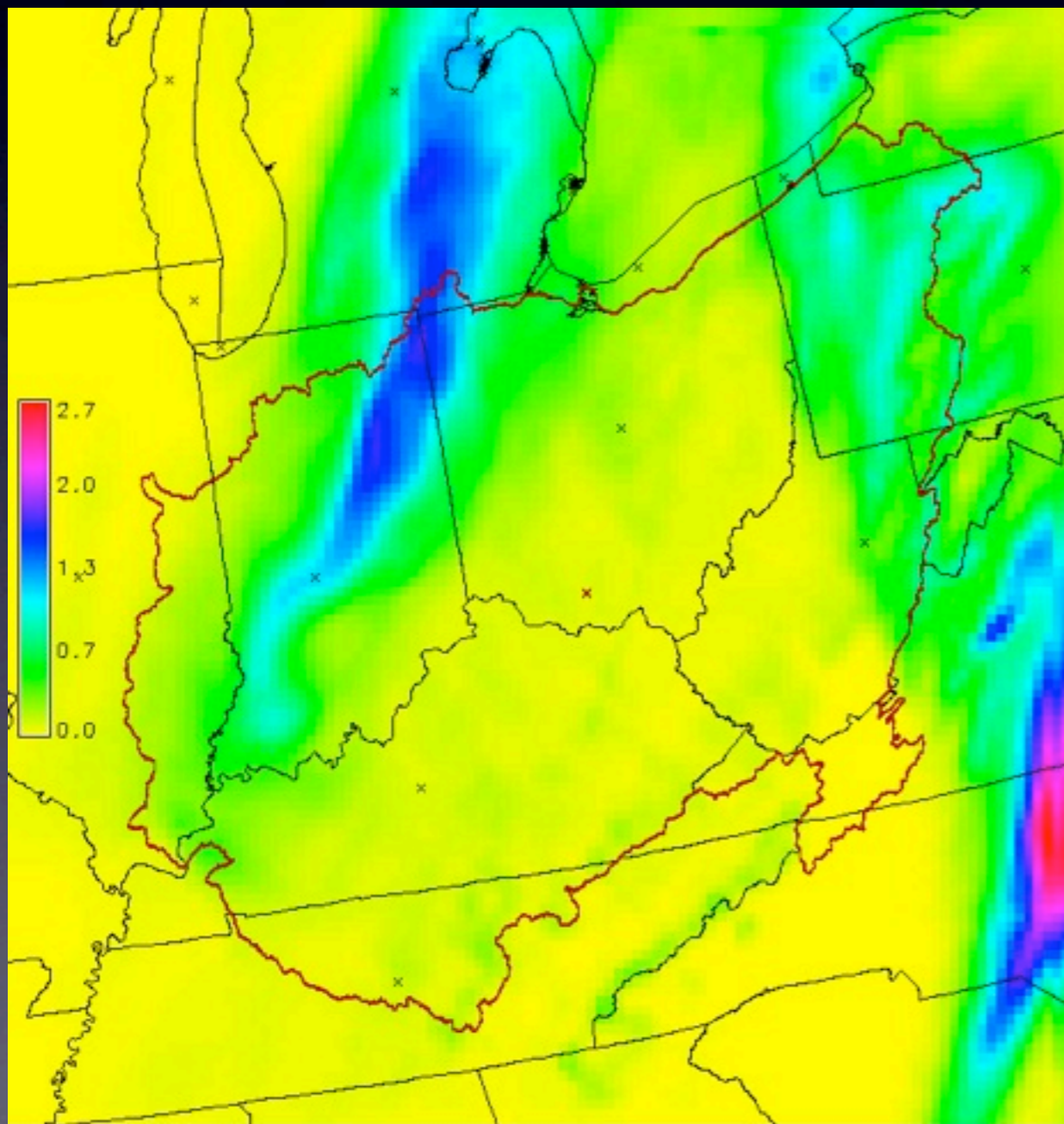
MM5 model

Observed

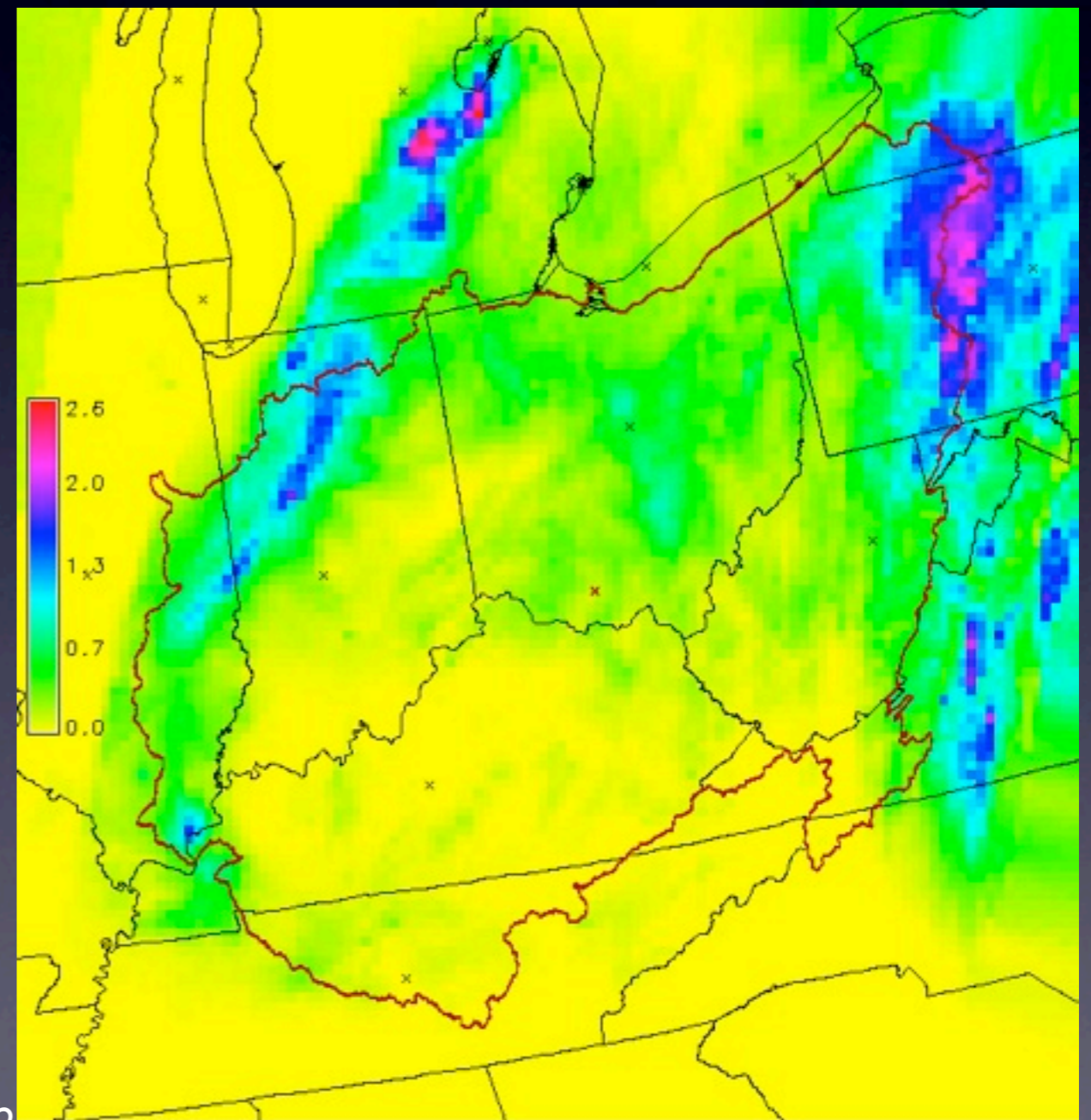


# Example 24-hr rainfall ending 11/17/2006-12Z

MM5 model

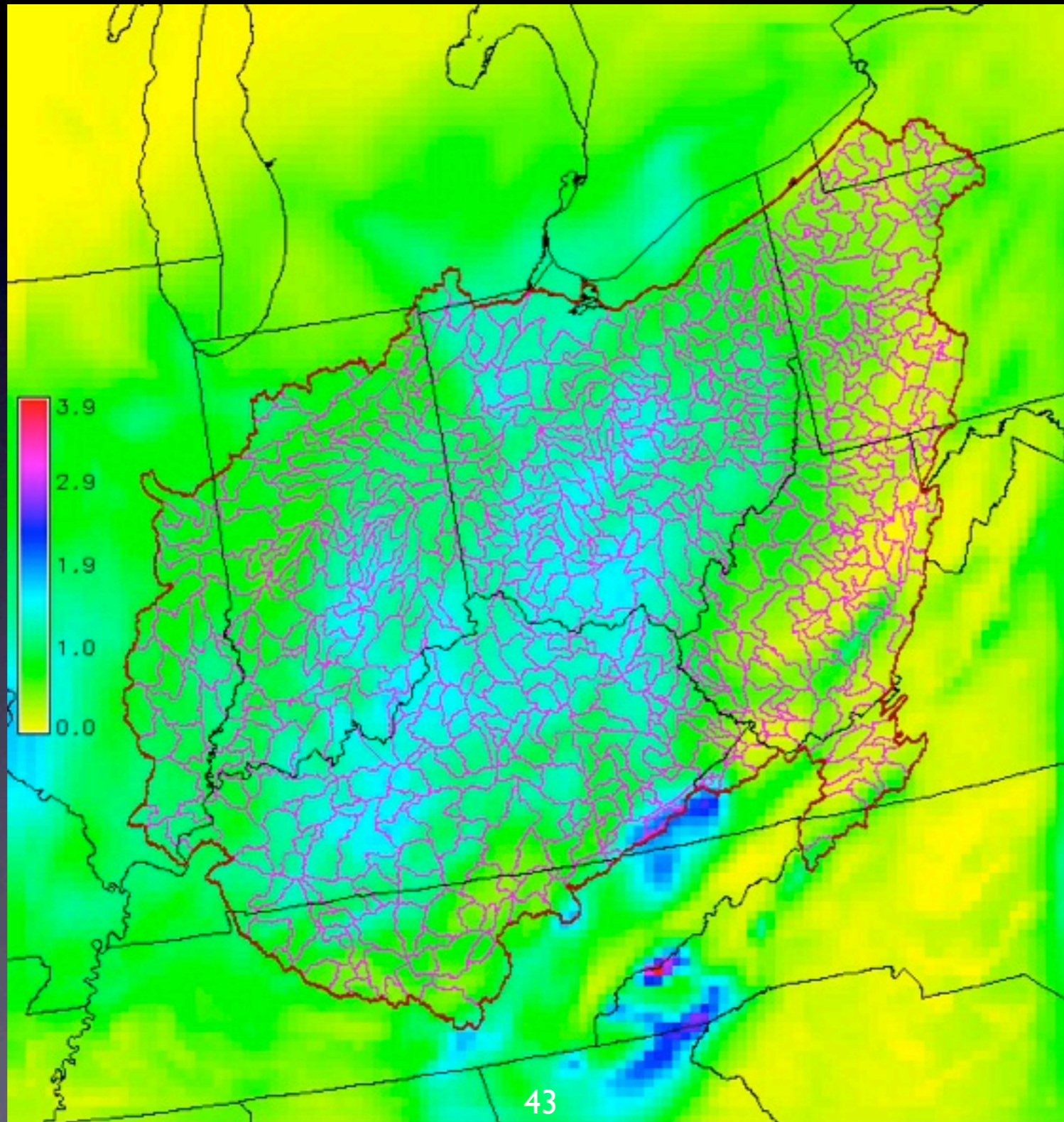


Observed



# 694 modeled subbasins

# 694 modeled subbasins



# Precipitation Observation Error

# Bias calculation

MPE xmrg  
precipitation

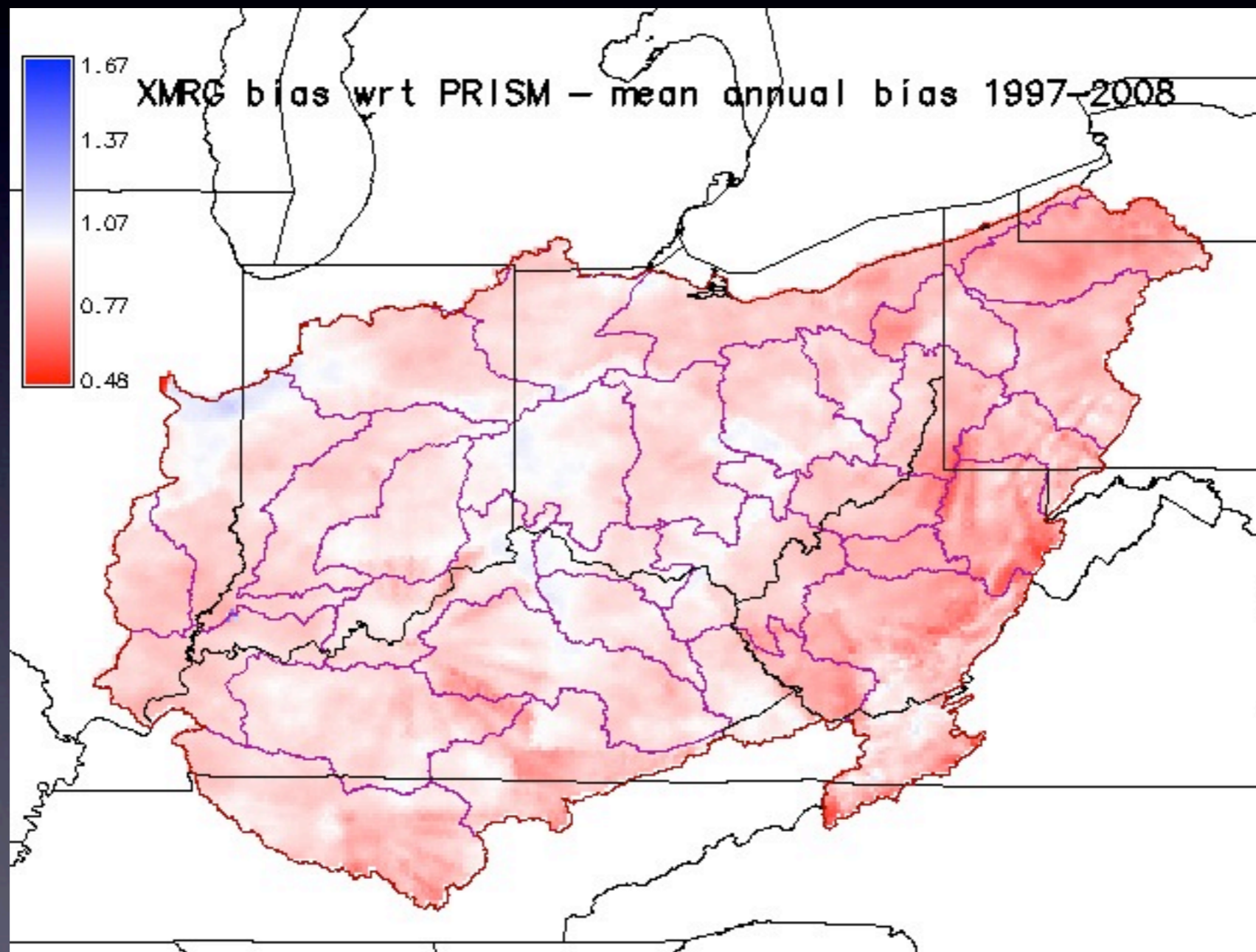


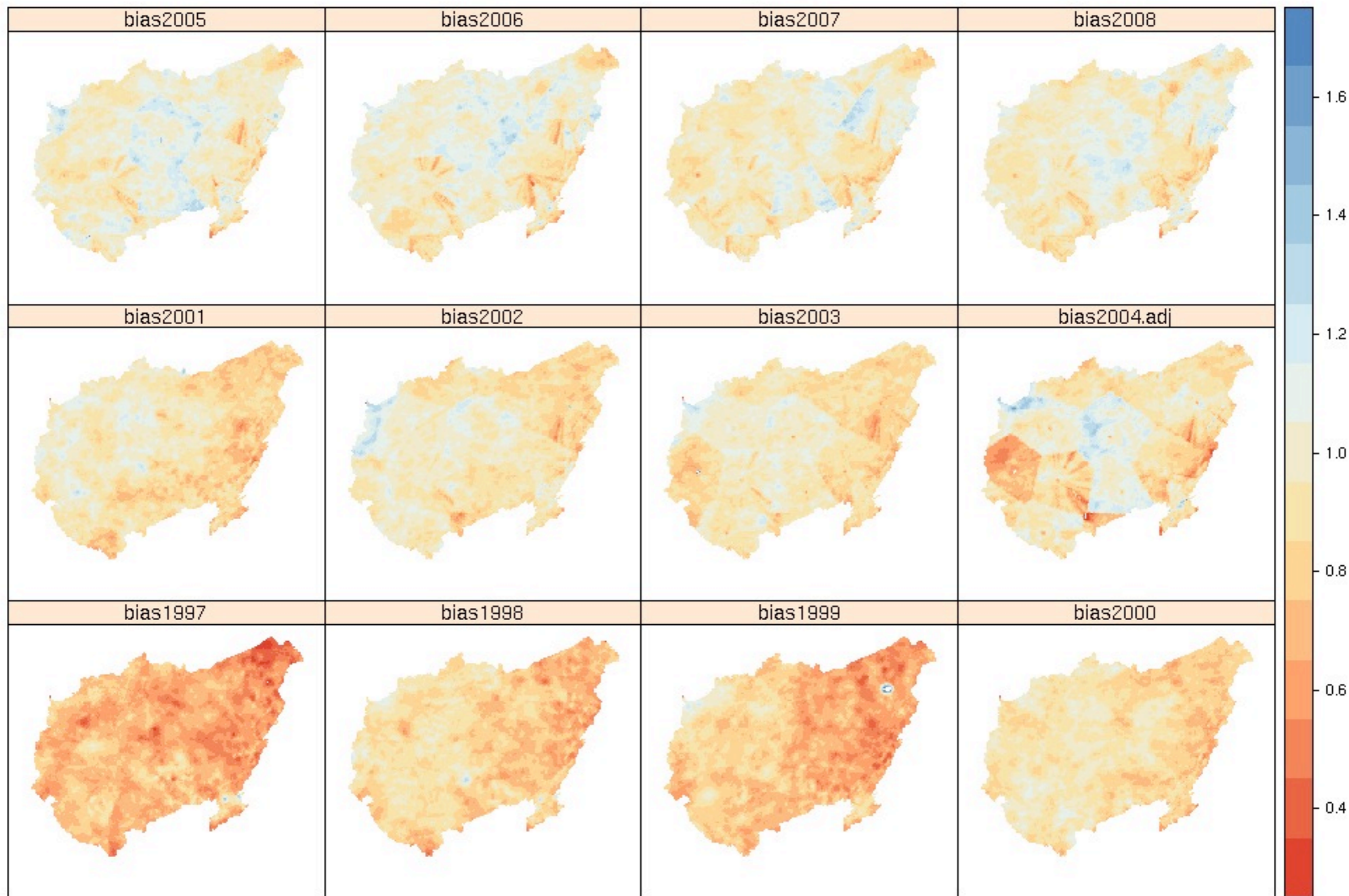
Co-op gauge network  
precipitation



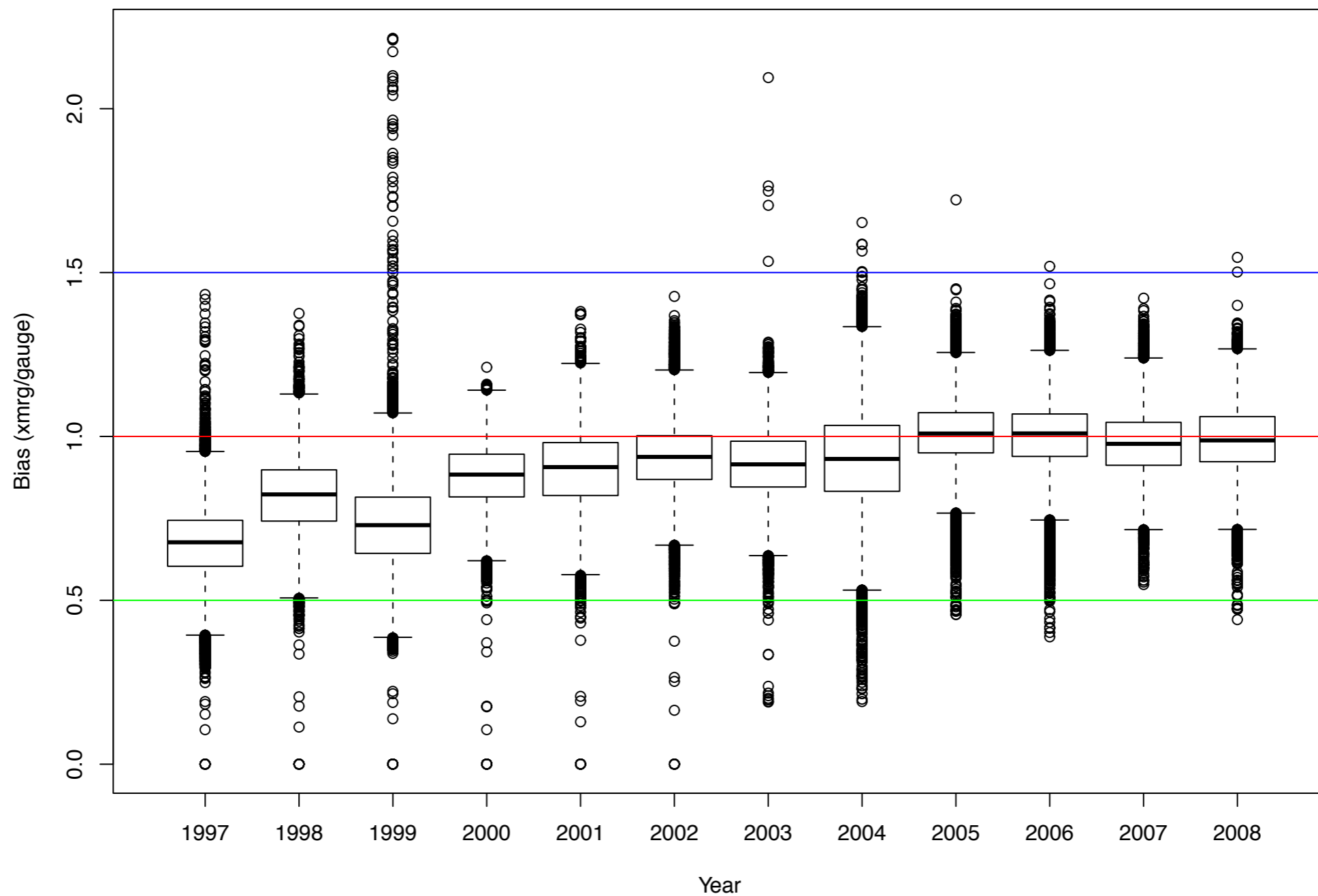
$$bias = \frac{MPE\ xmrg\ precipitation}{Coop\ raingauge\ network\ precipitation}$$

# Mean Annual Bias 1997 - 2008

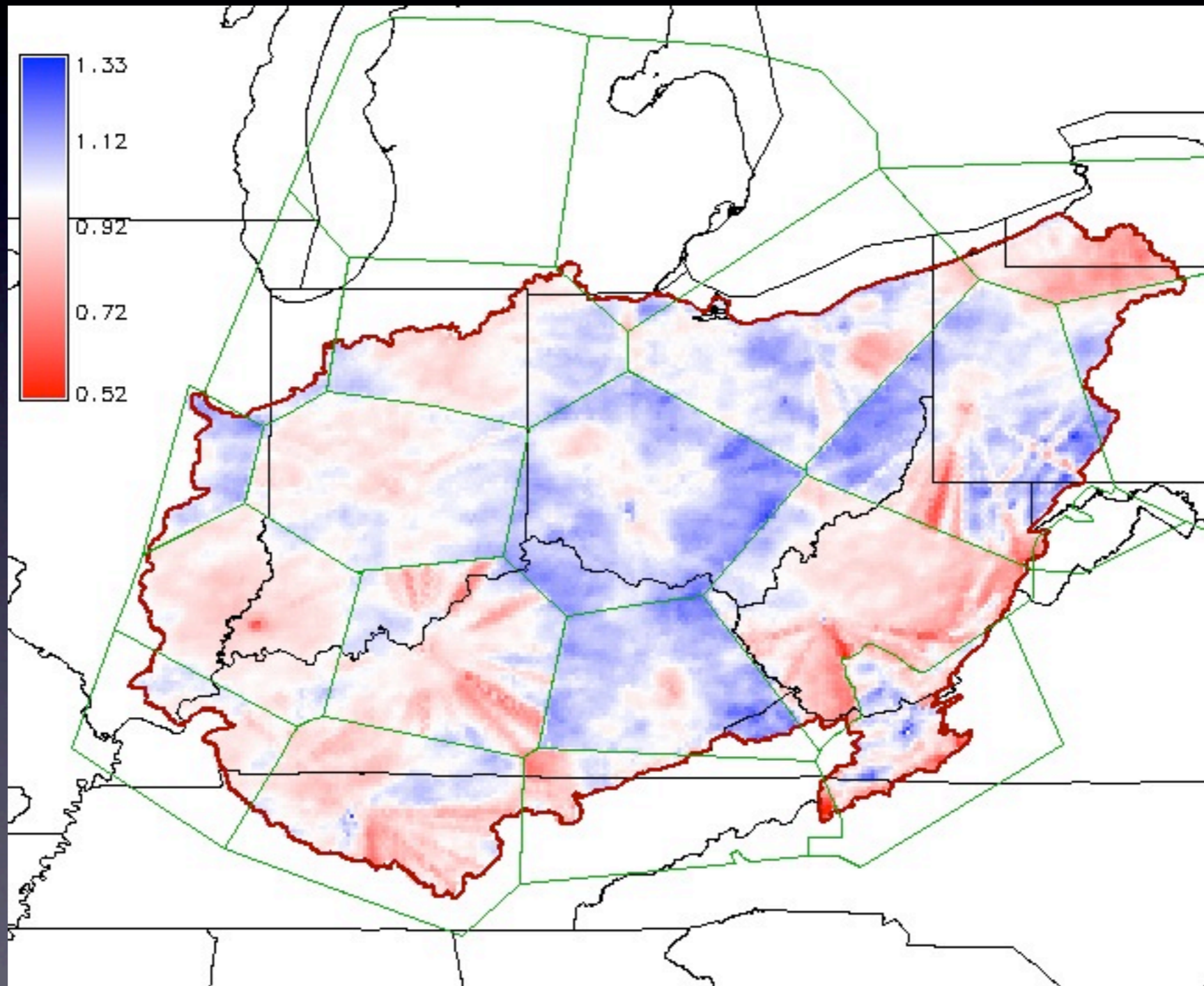




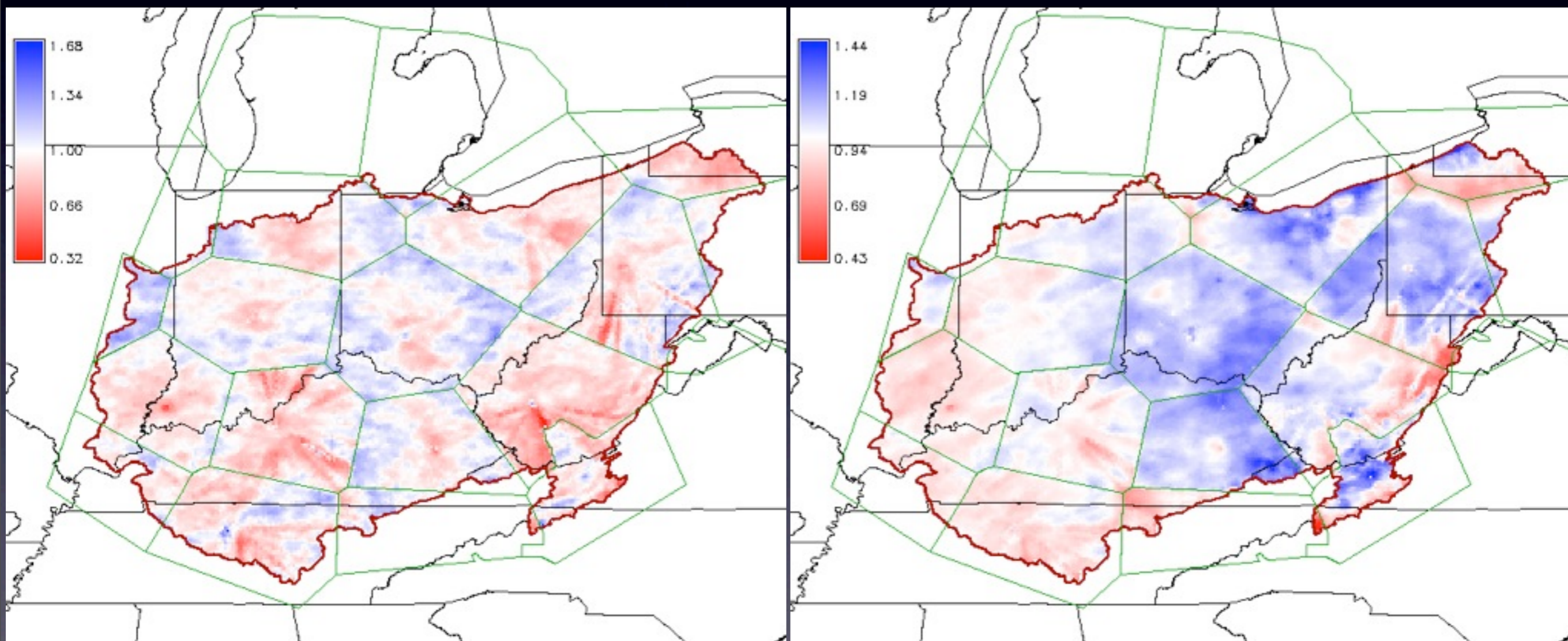
# *xmrg* Bias by Year



# 2005-2008 average bias



# 2005 - 2008 mean seasonal bias

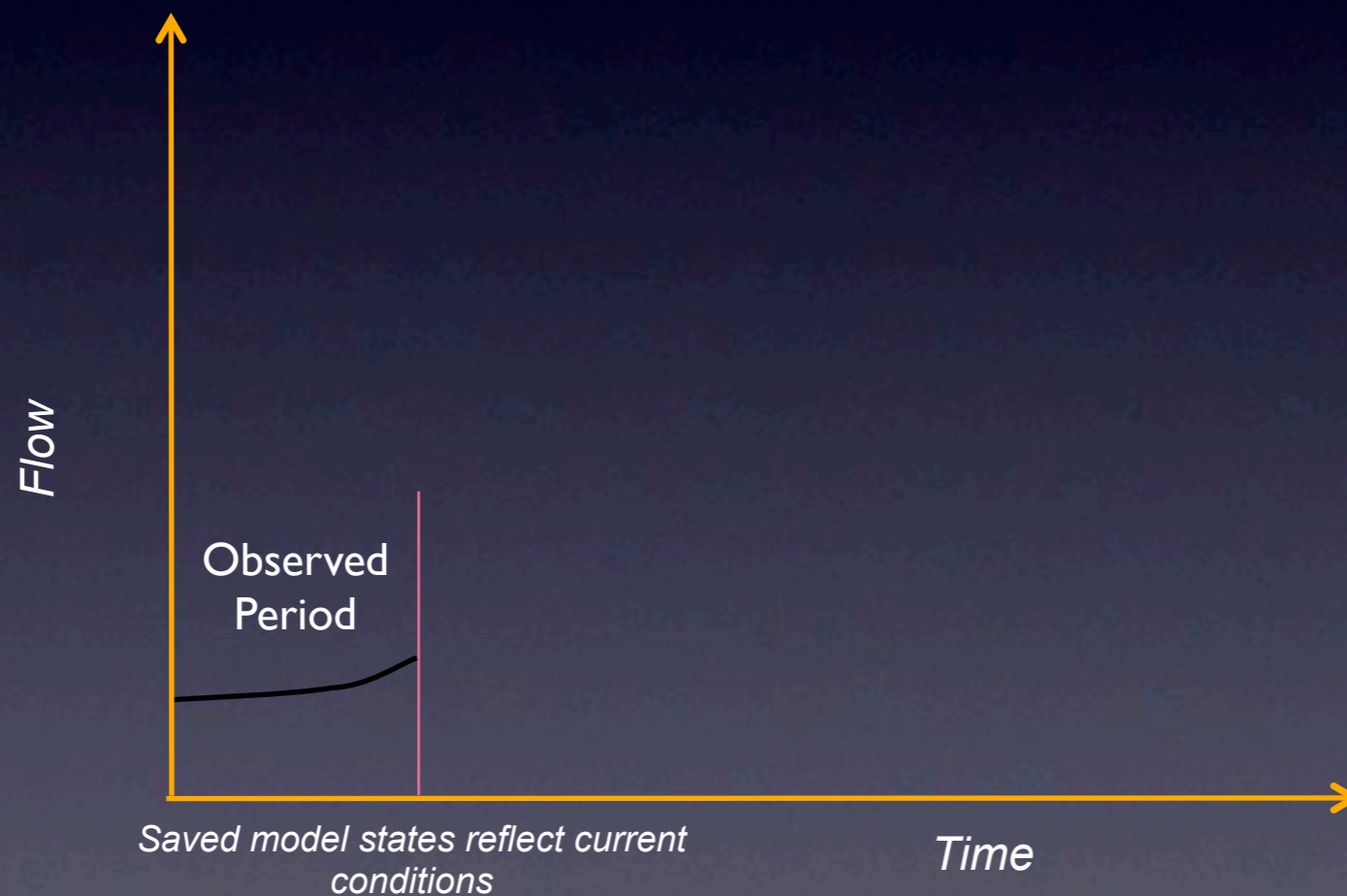


JJA

DJF

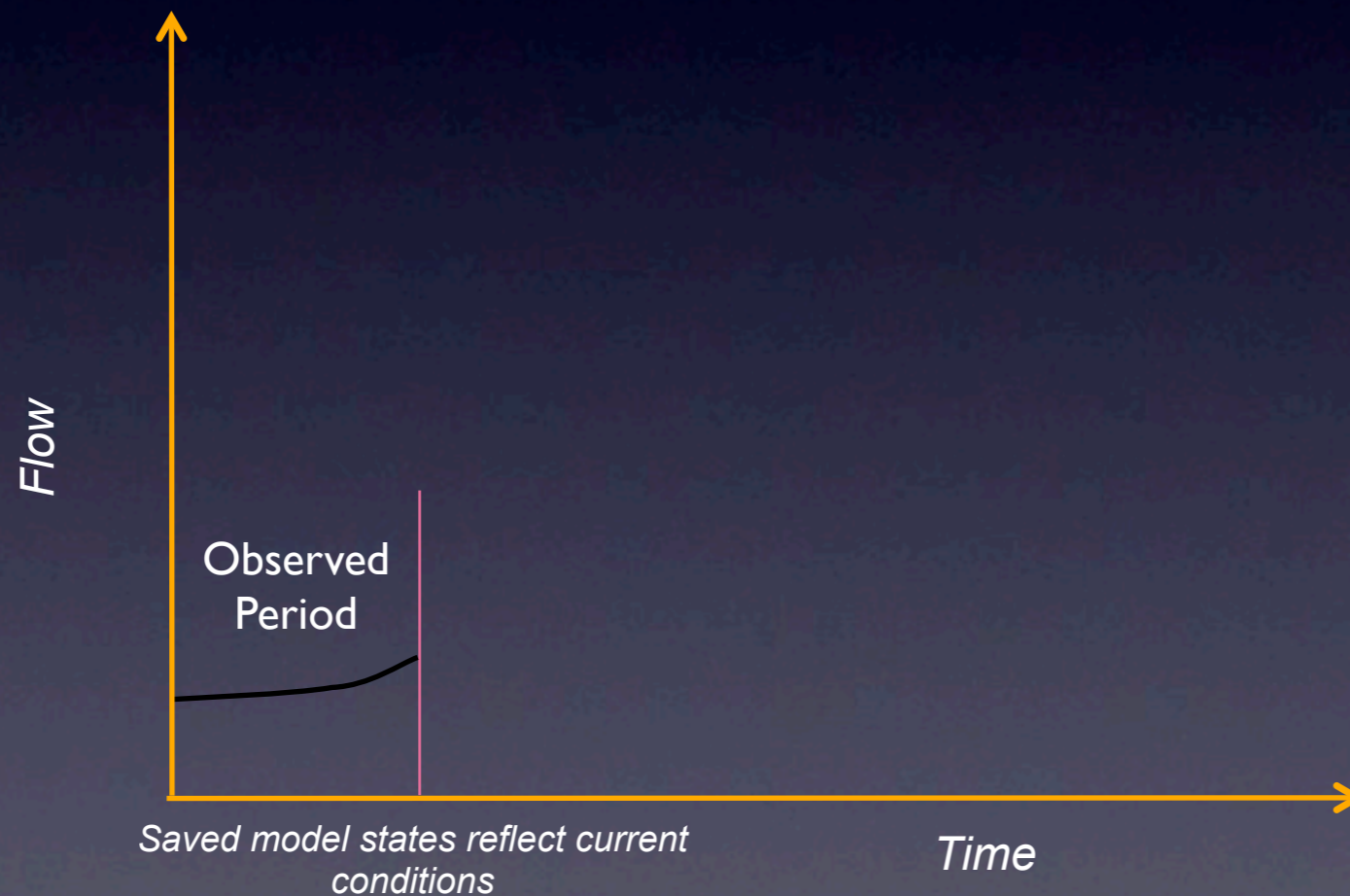
# Short lead-time probabilistic streamflow forecasting (MMEFS)

# Ensemble Streamflow Prediction

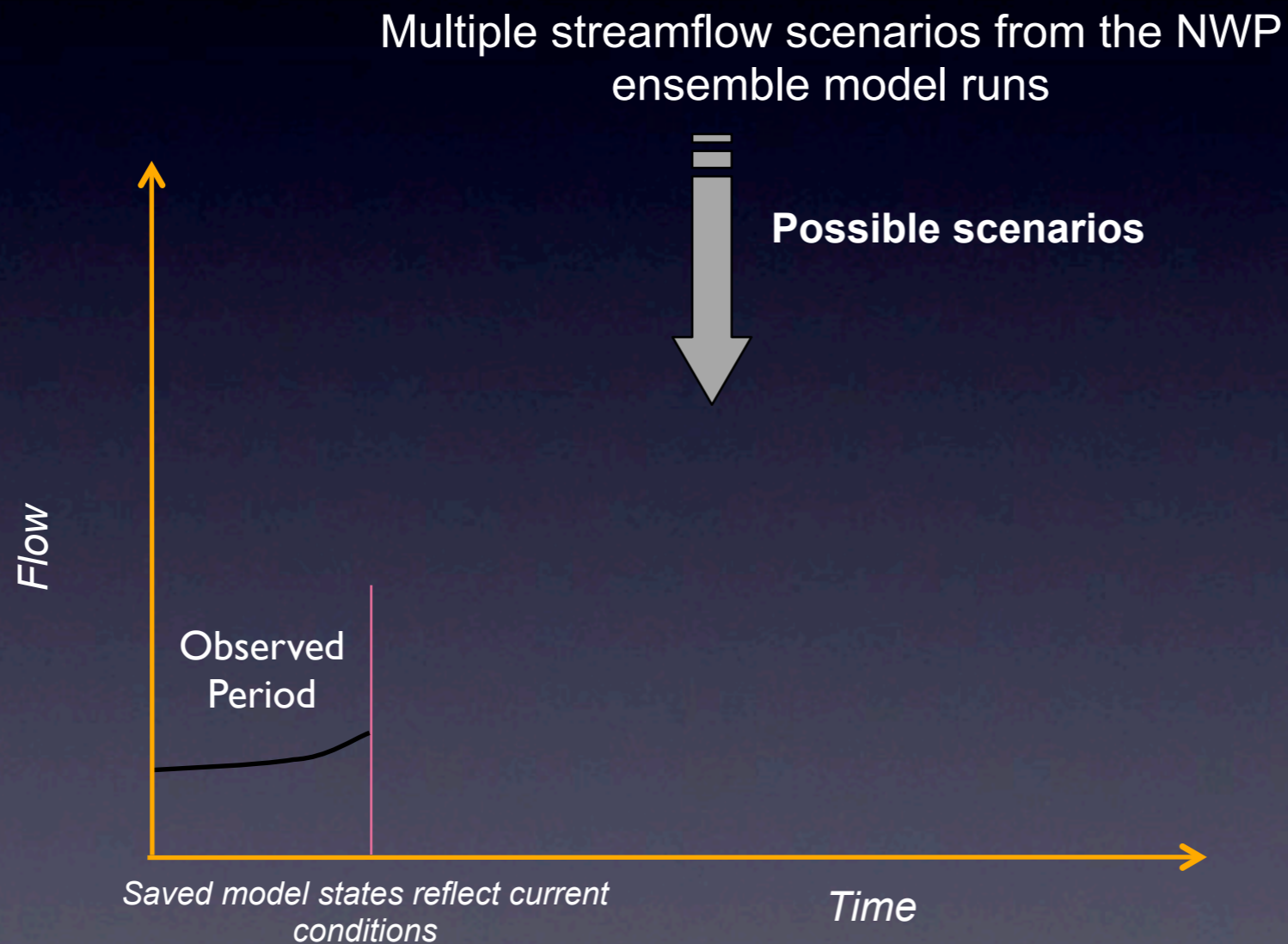


# Ensemble Streamflow Prediction

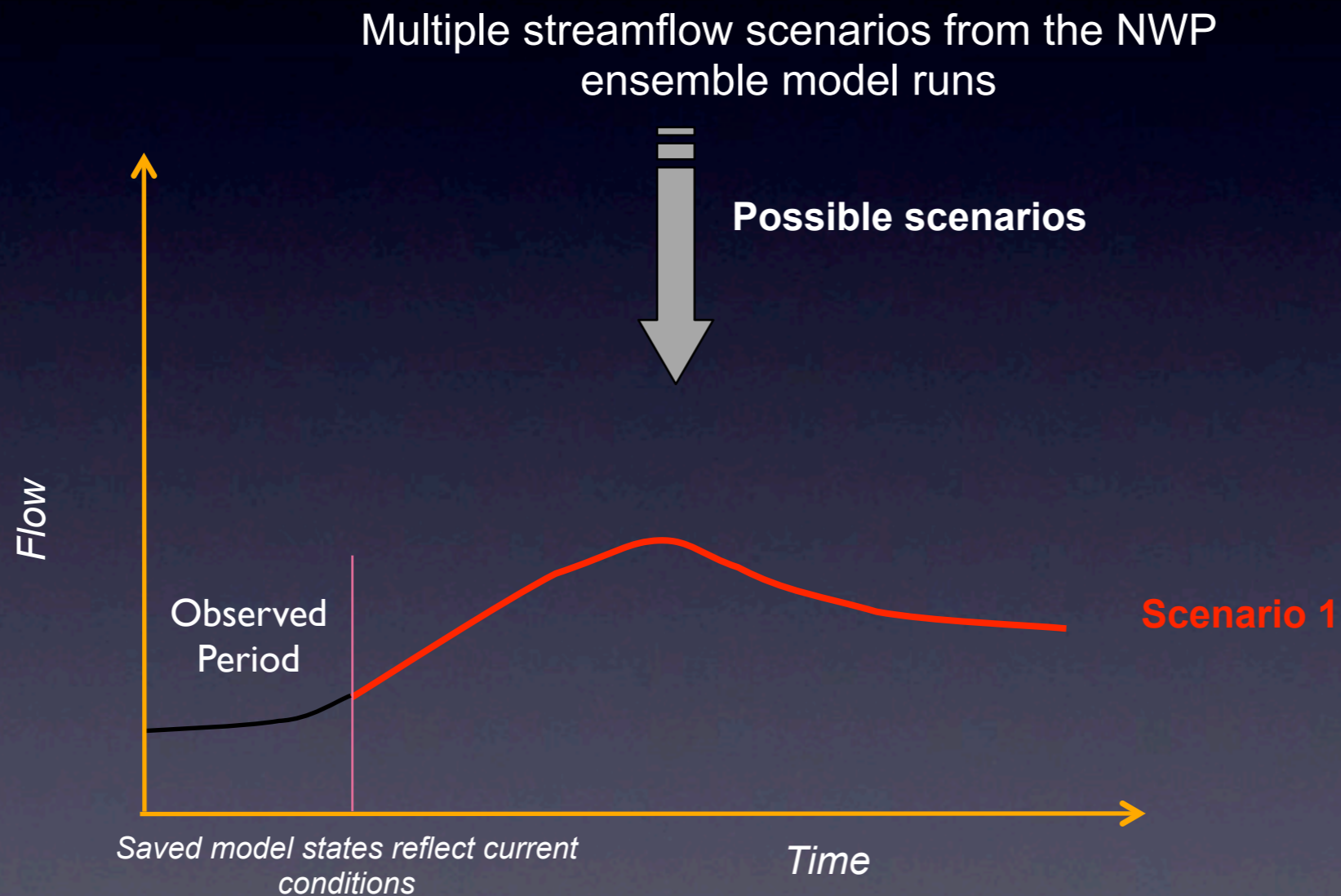
Multiple streamflow scenarios from the NWP ensemble model runs



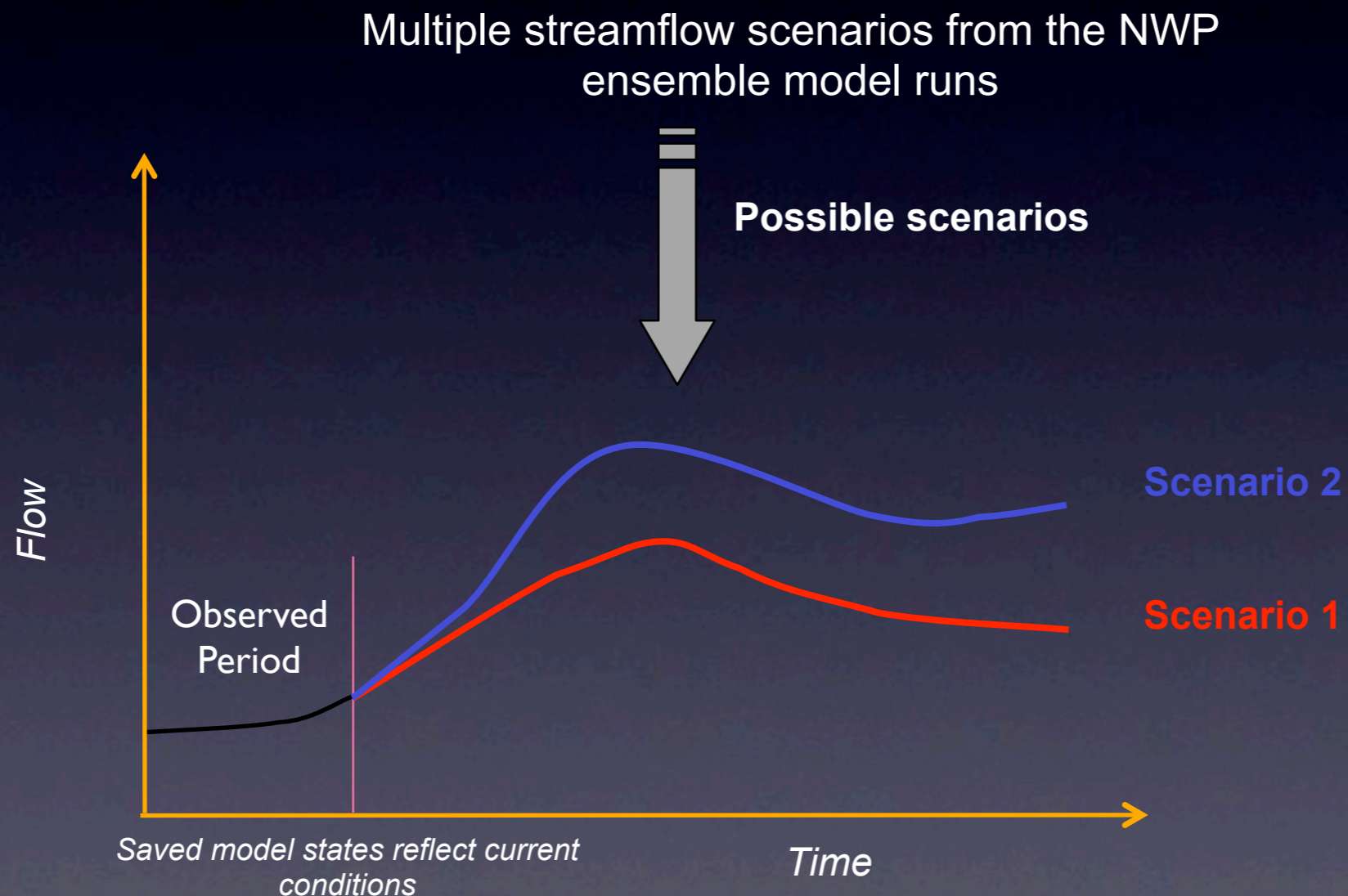
# Ensemble Streamflow Prediction



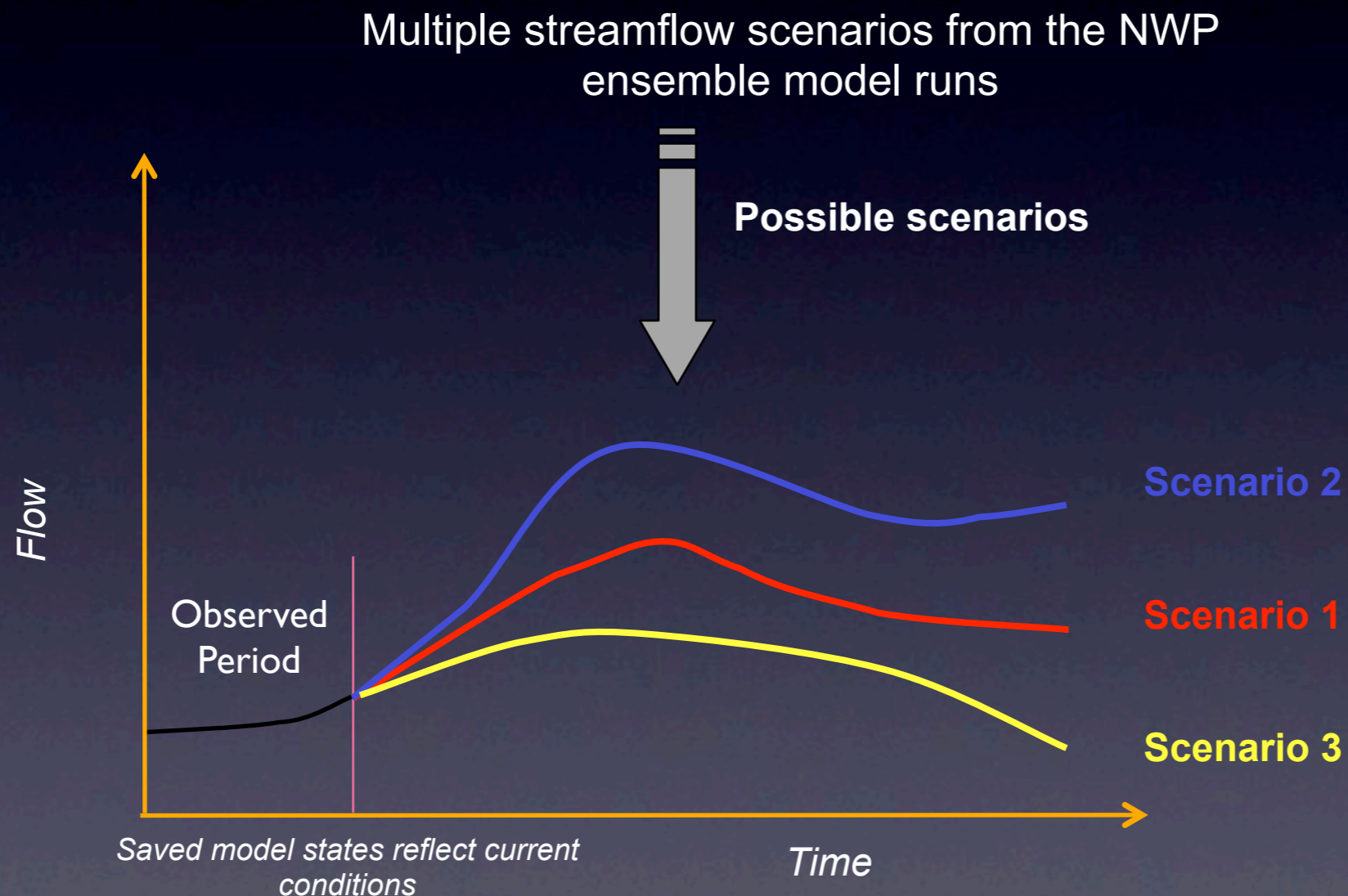
# Ensemble Streamflow Prediction



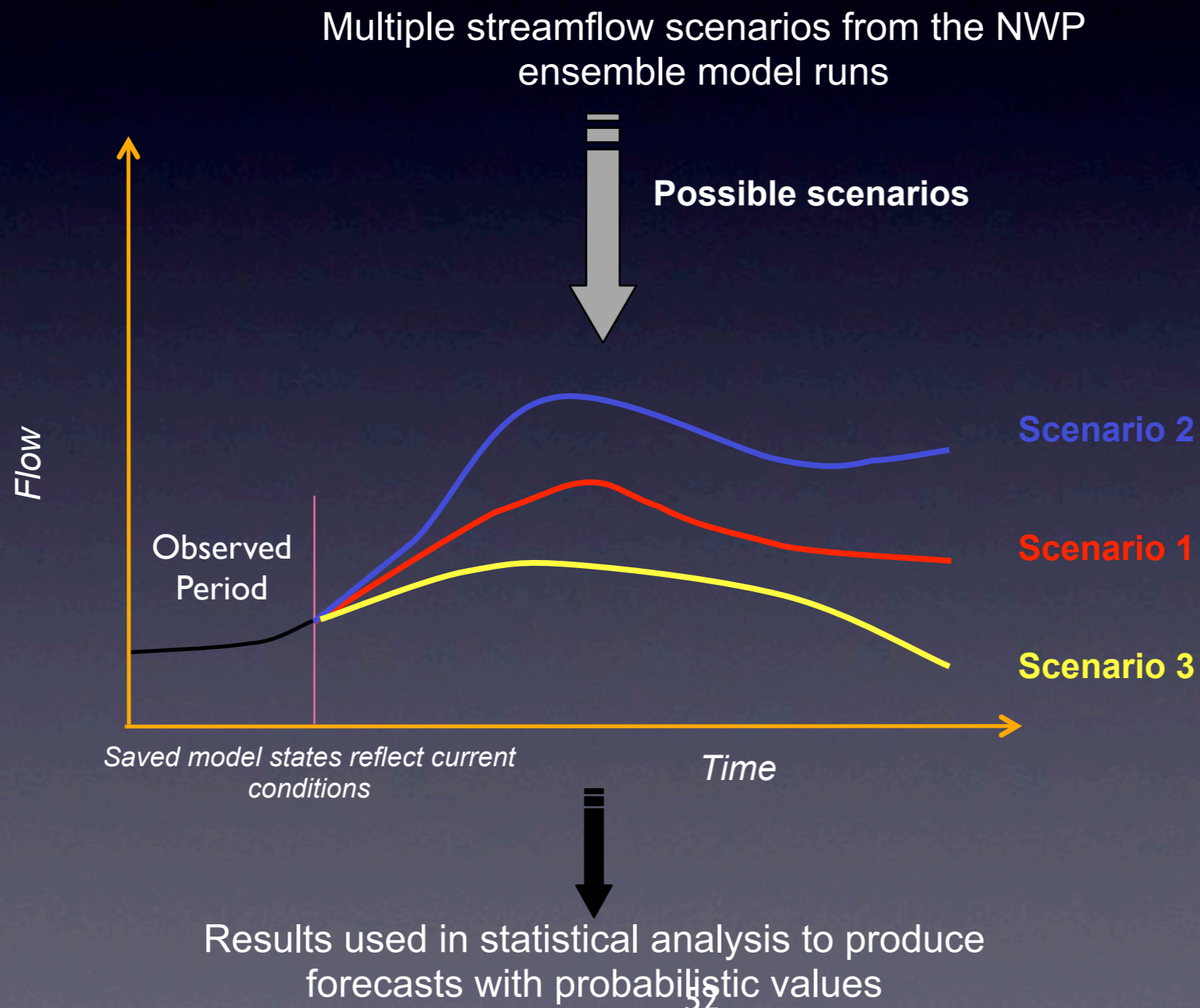
# Ensemble Streamflow Prediction



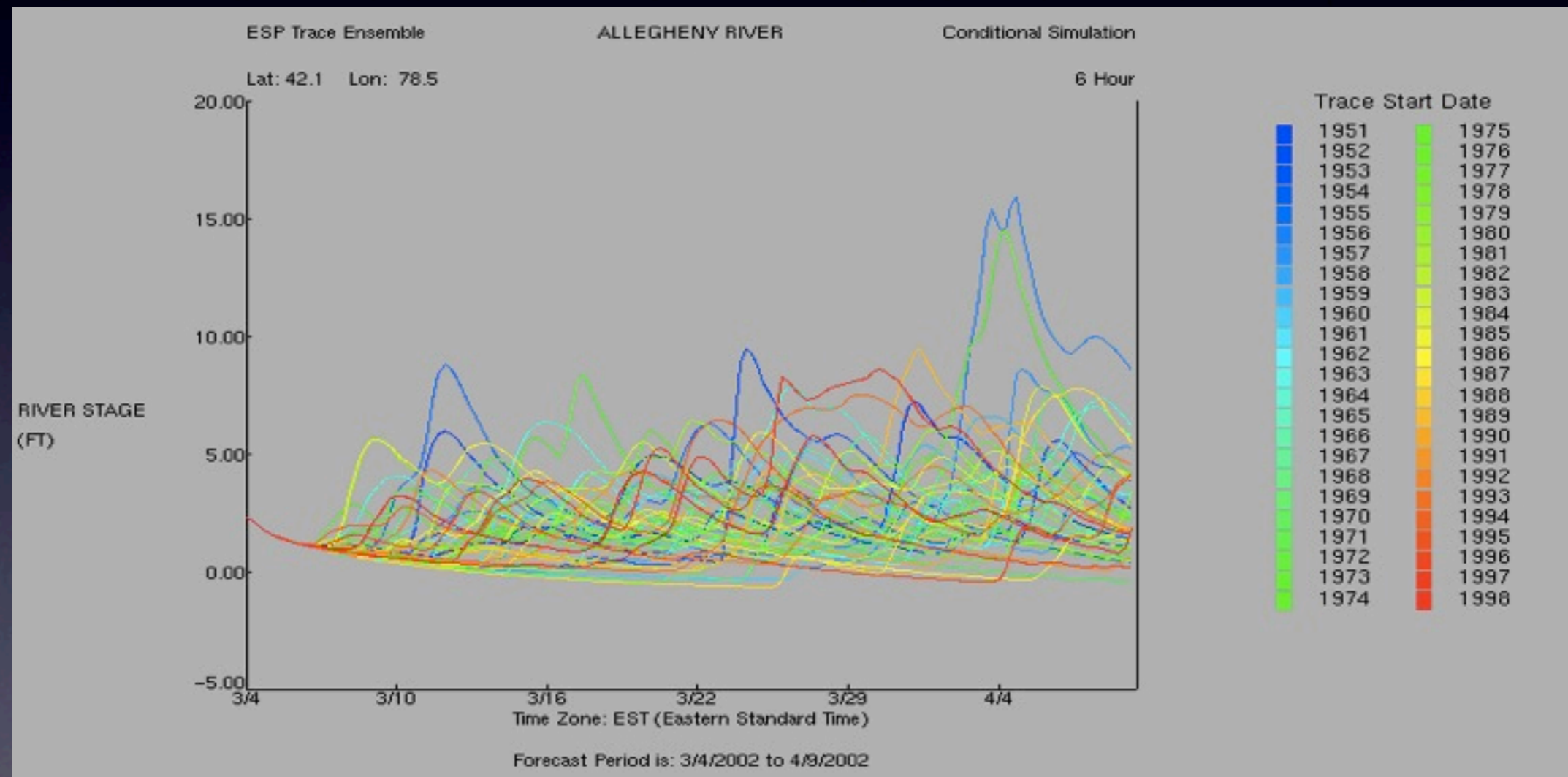
# Ensemble Streamflow Prediction



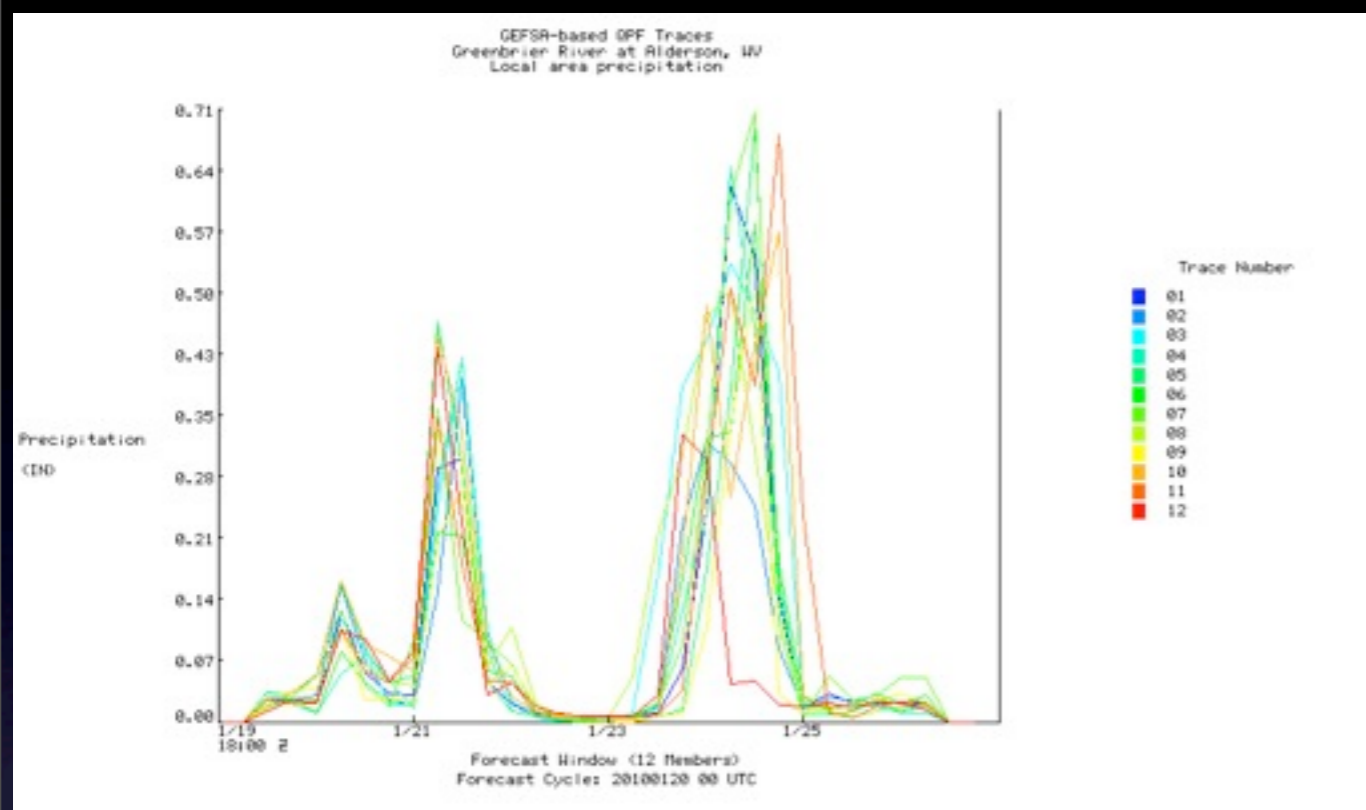
# Ensemble Streamflow Prediction



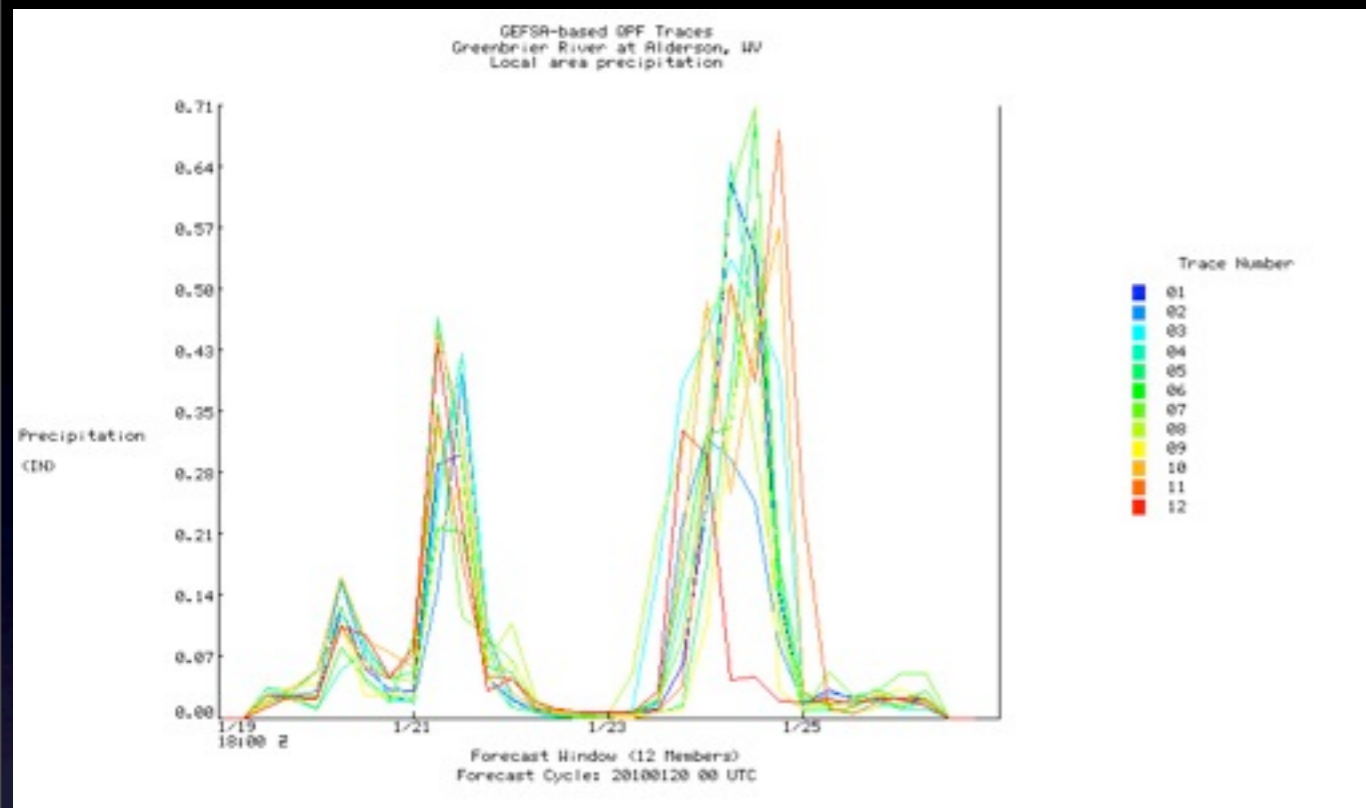
# ESP Ensemble Traces



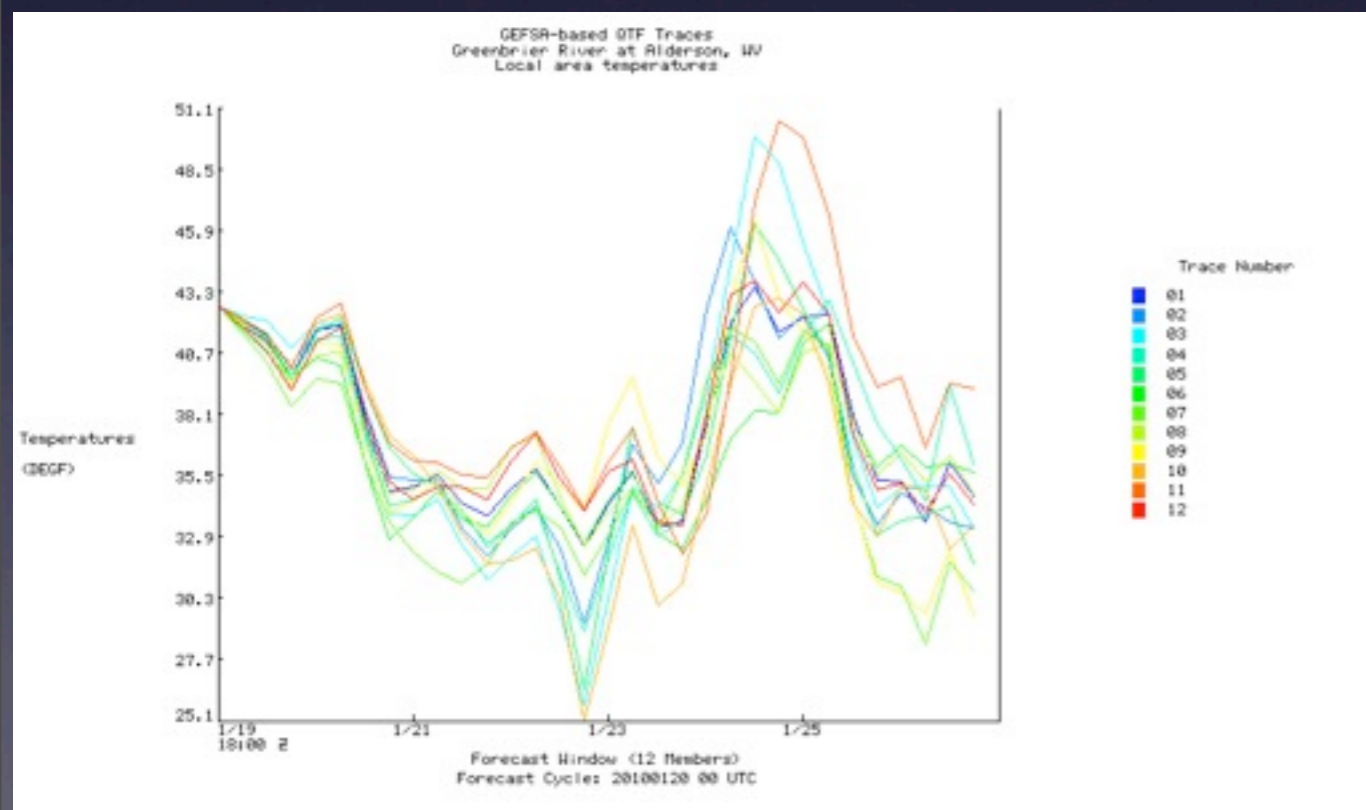
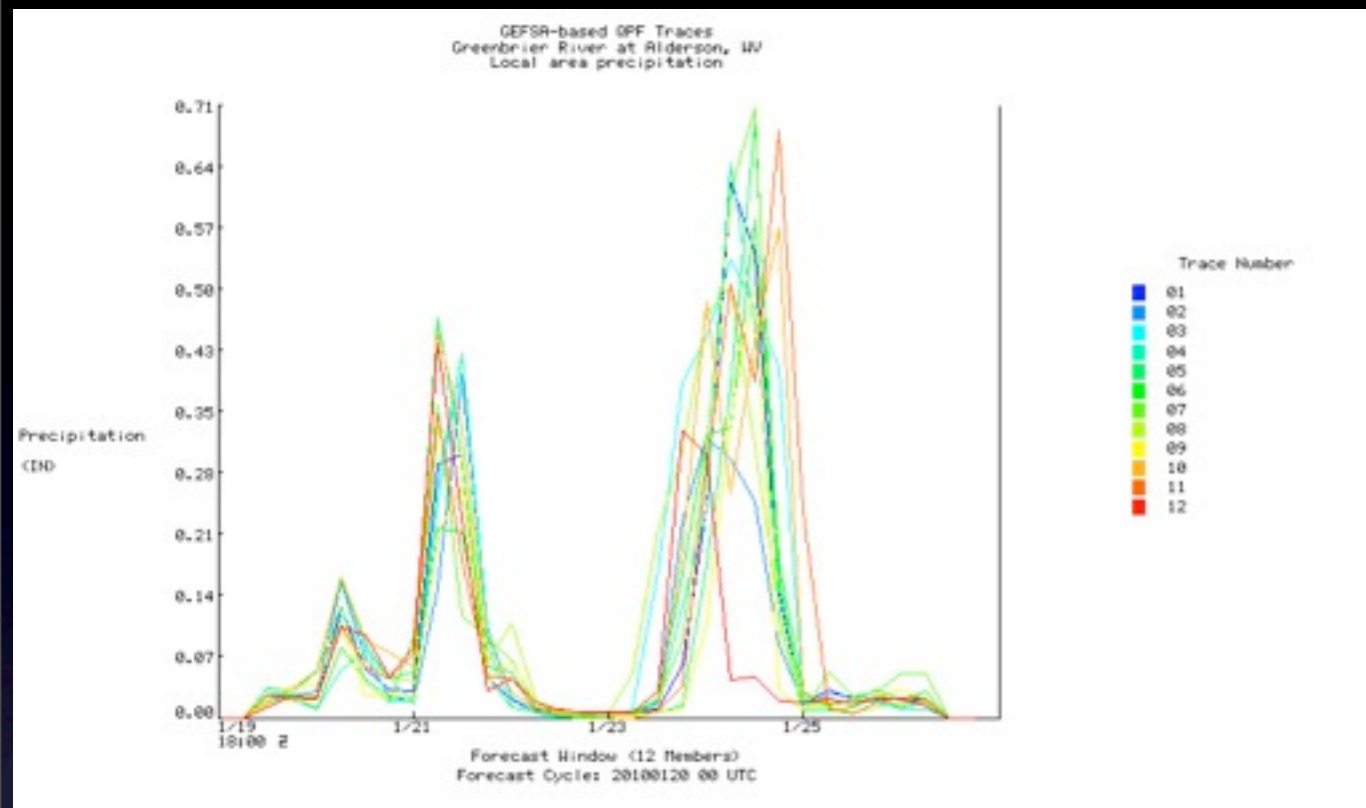




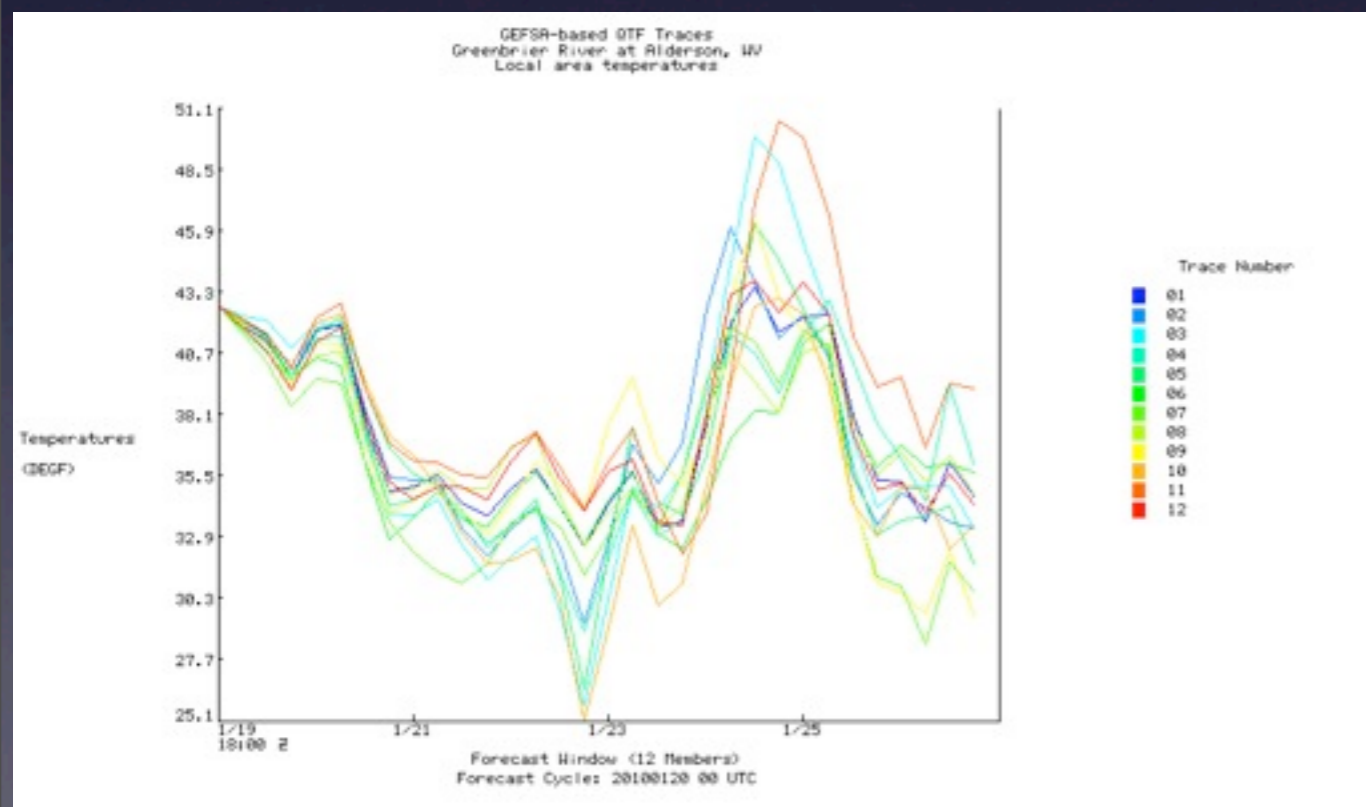
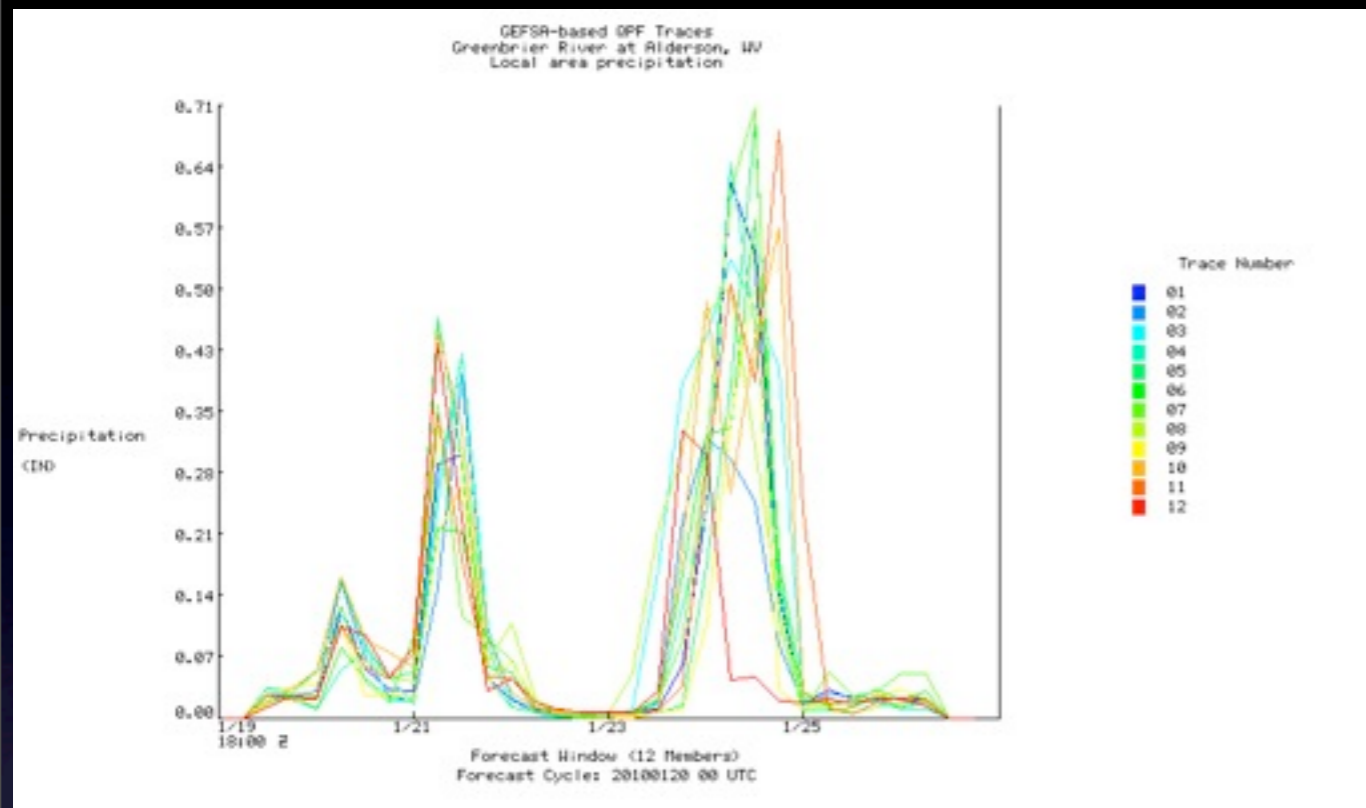
# Precipitation



# Precipitation

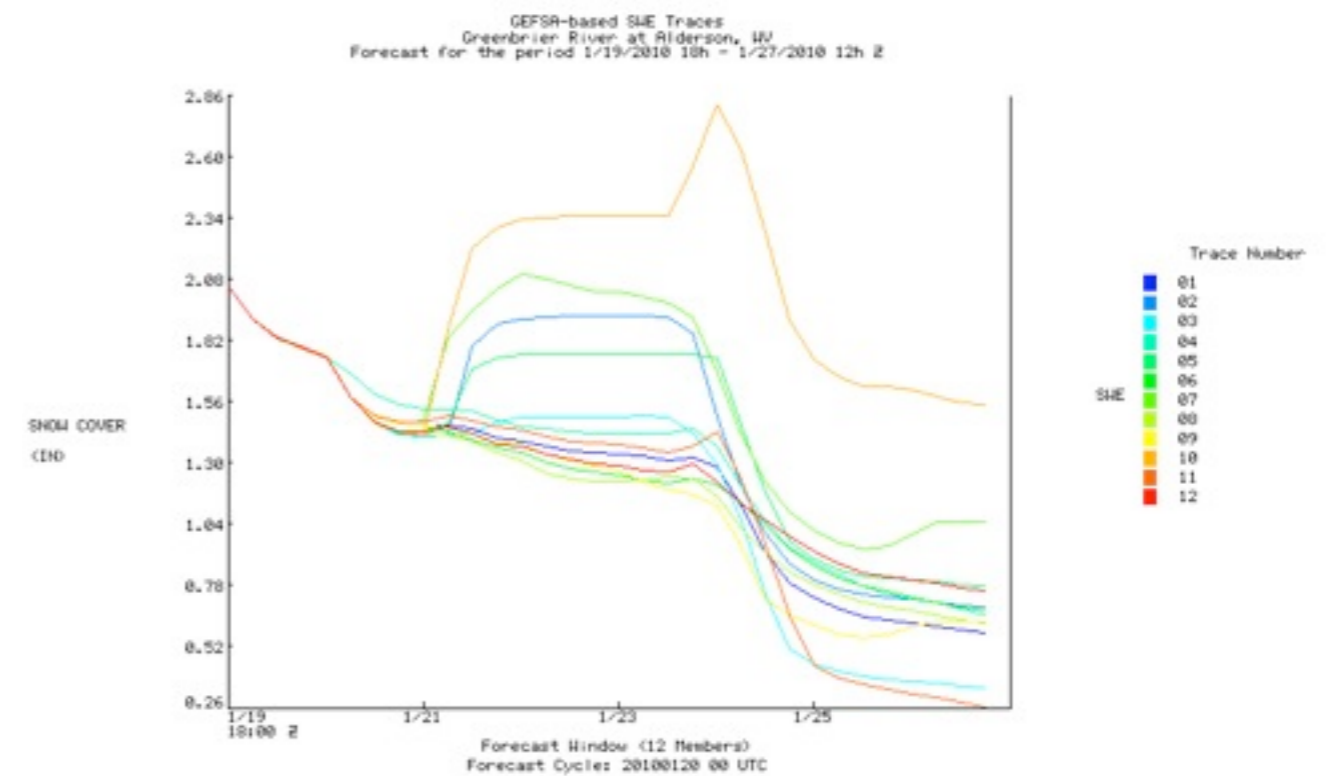
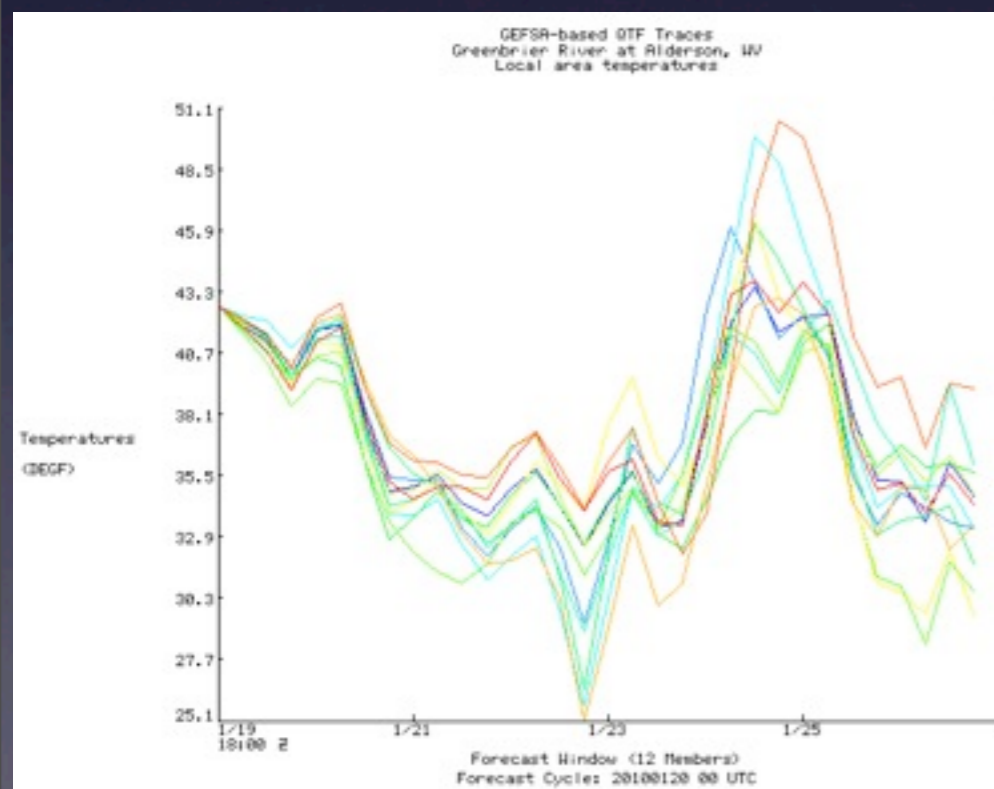
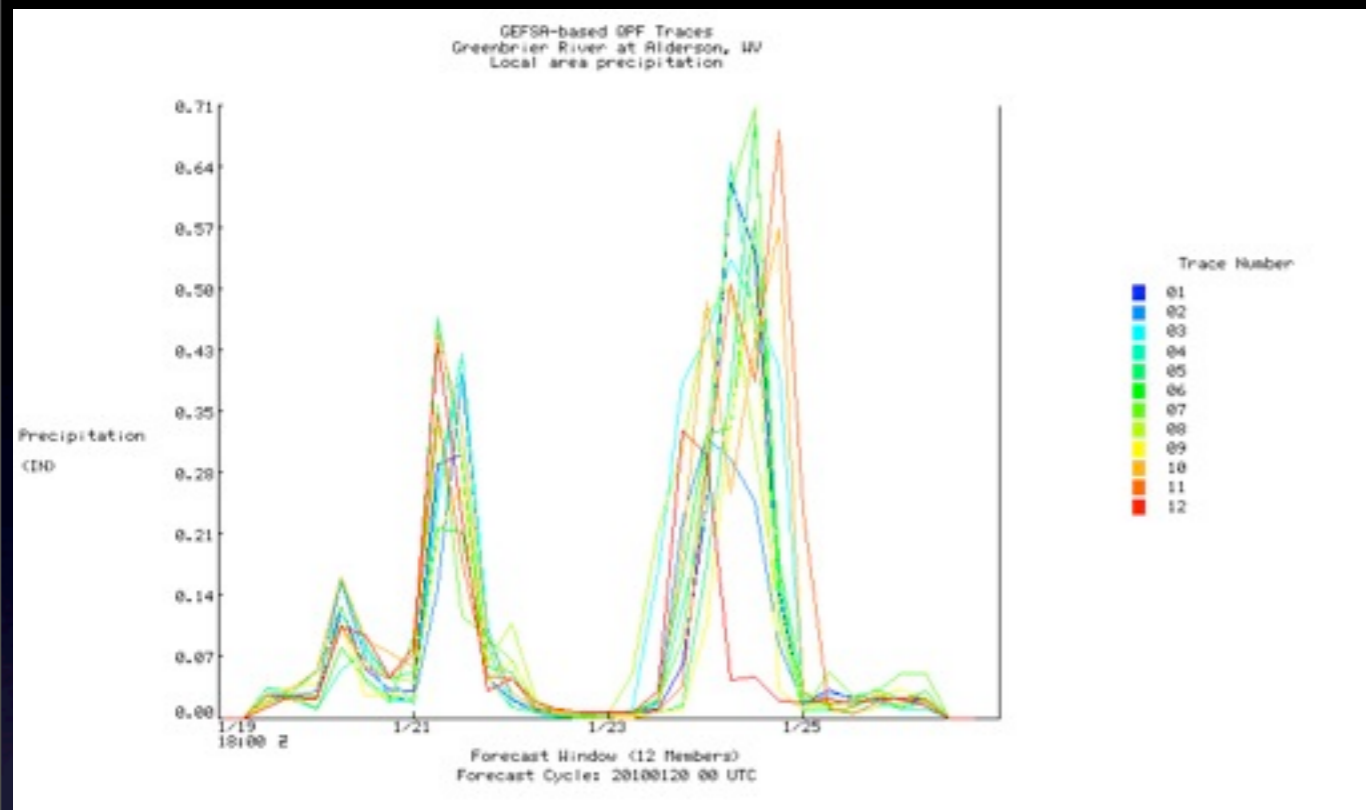


## Precipitation



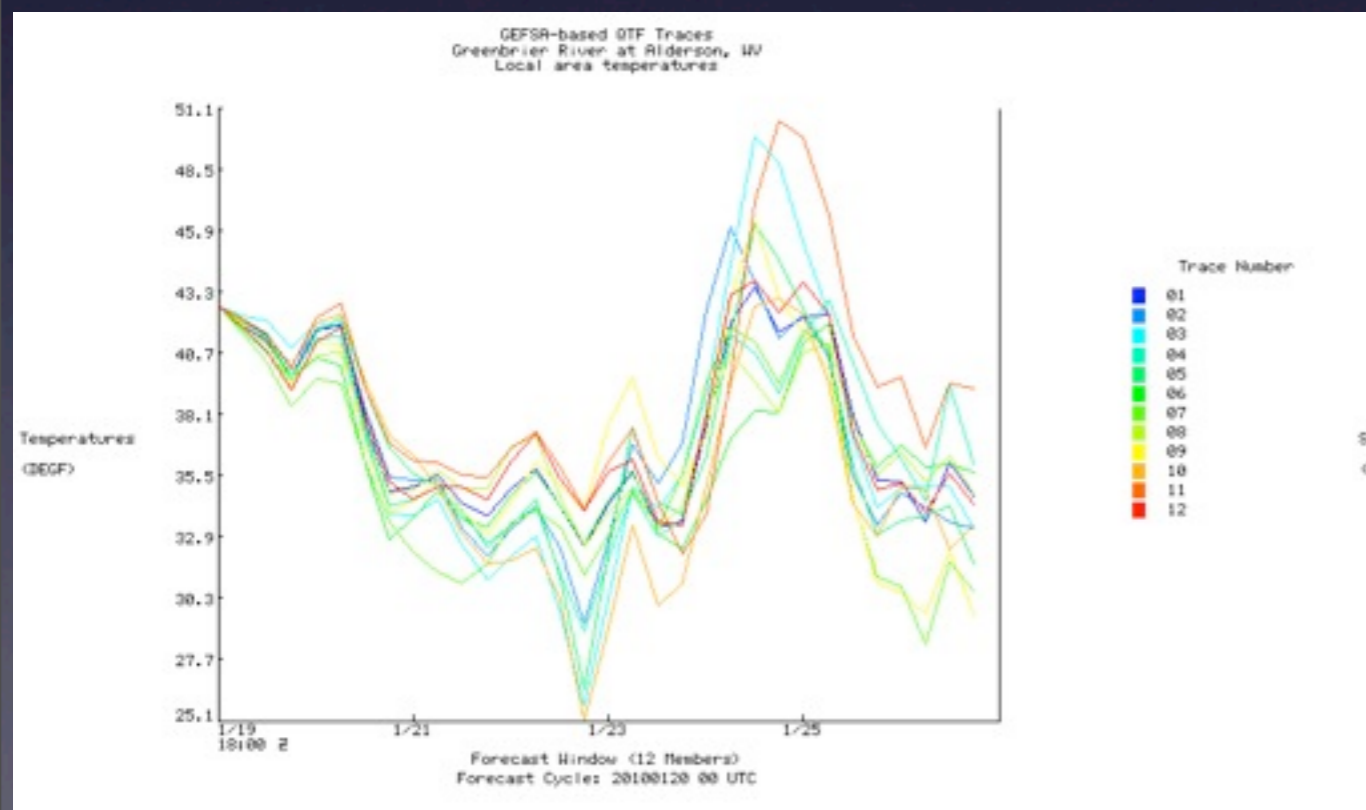
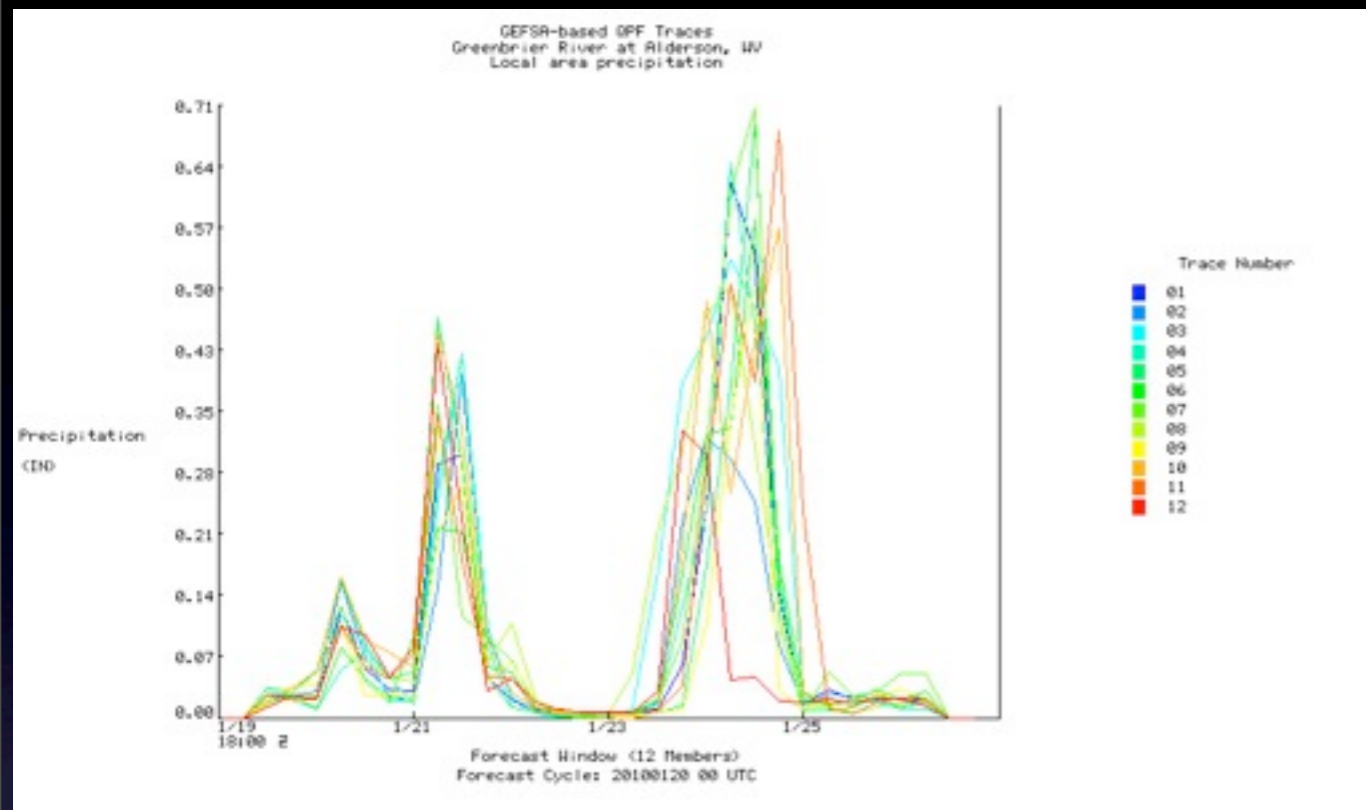
## Temperature

## Precipitation

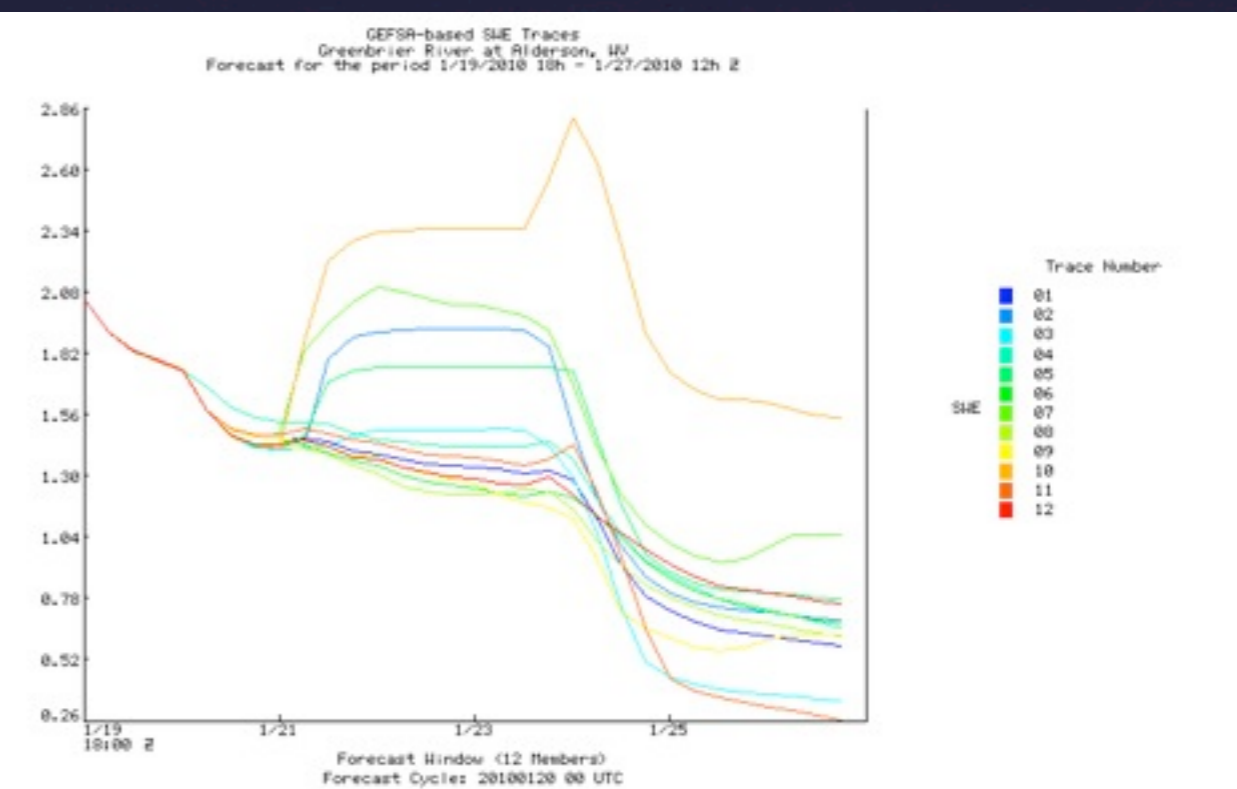


## Temperature

## Precipitation

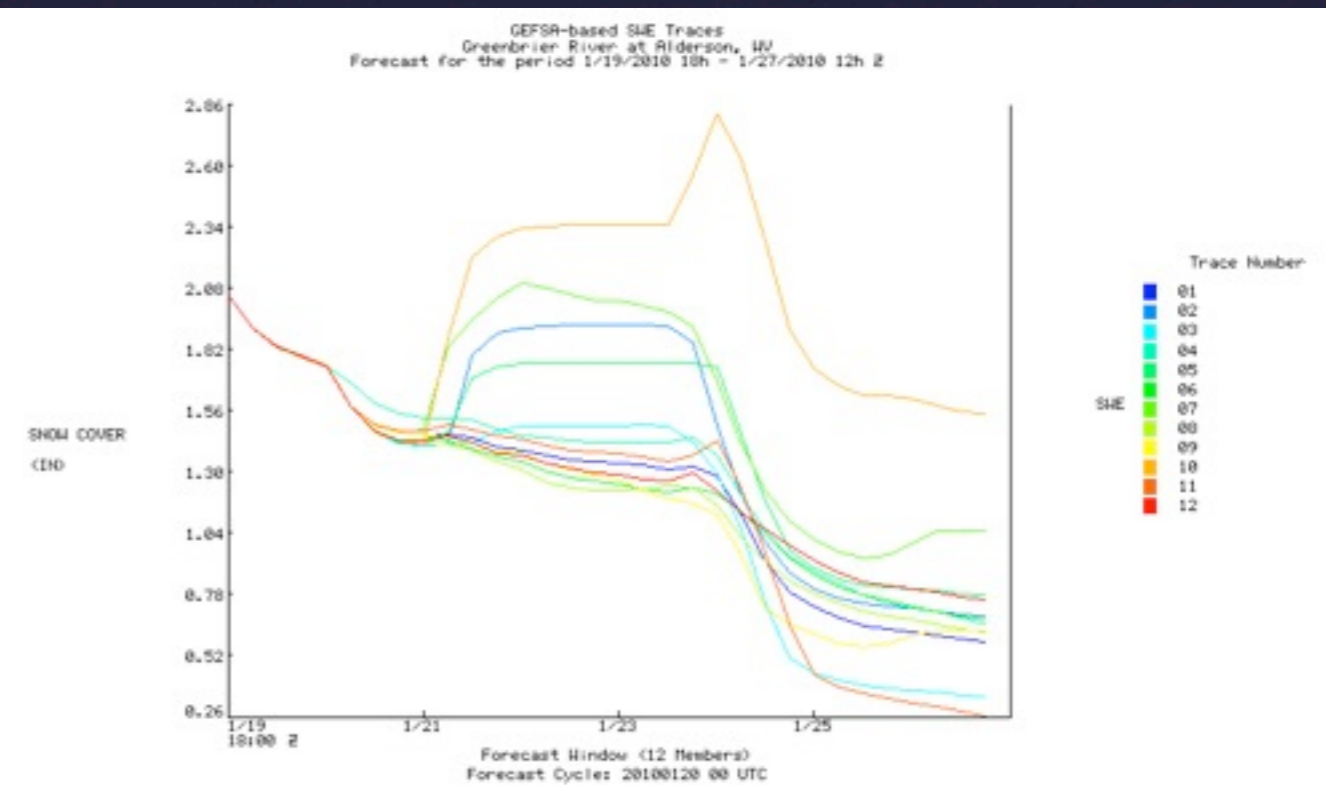
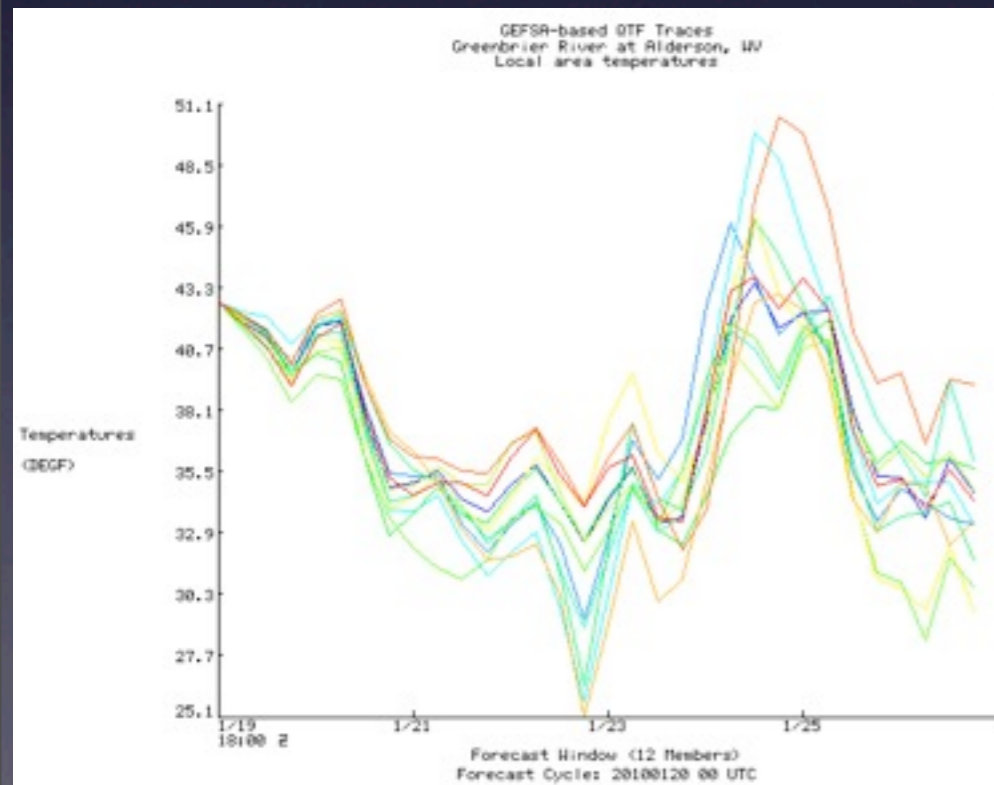
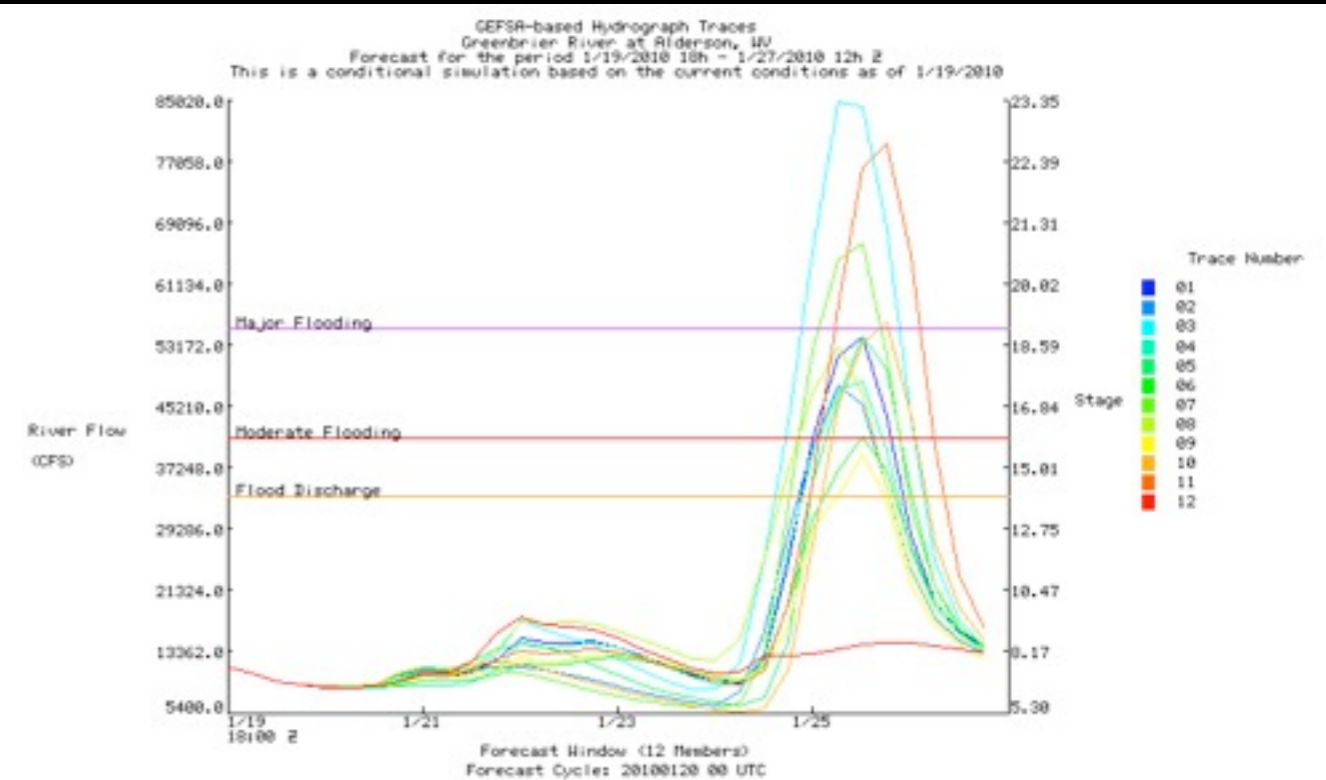
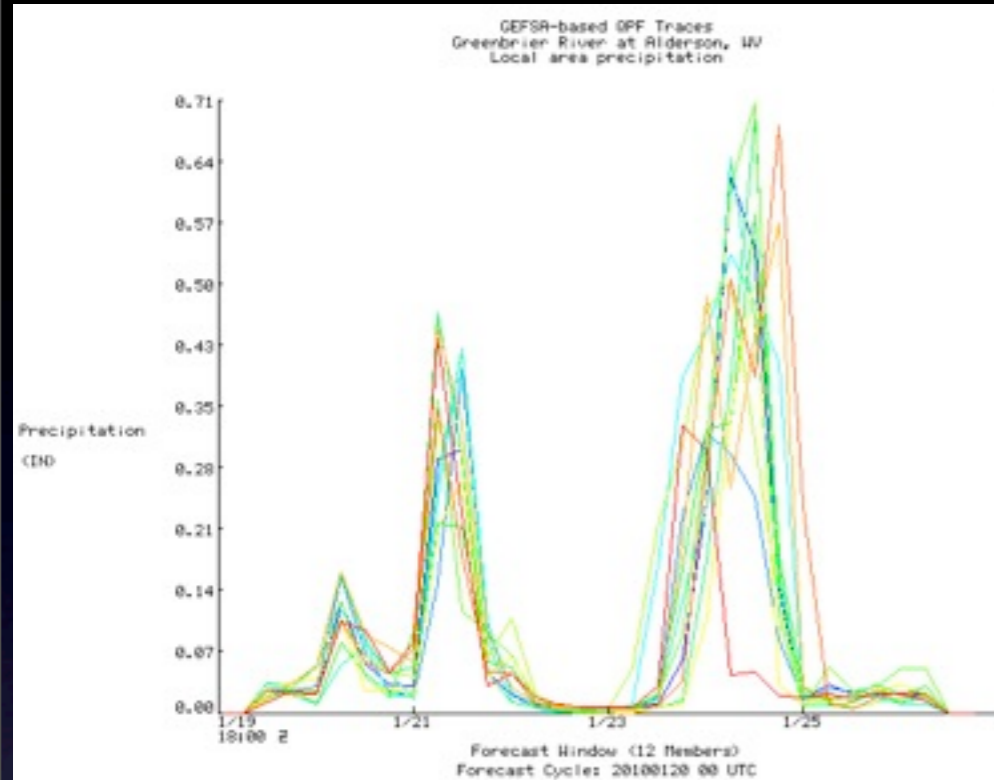


## Temperature



## Snow Water Equivalent

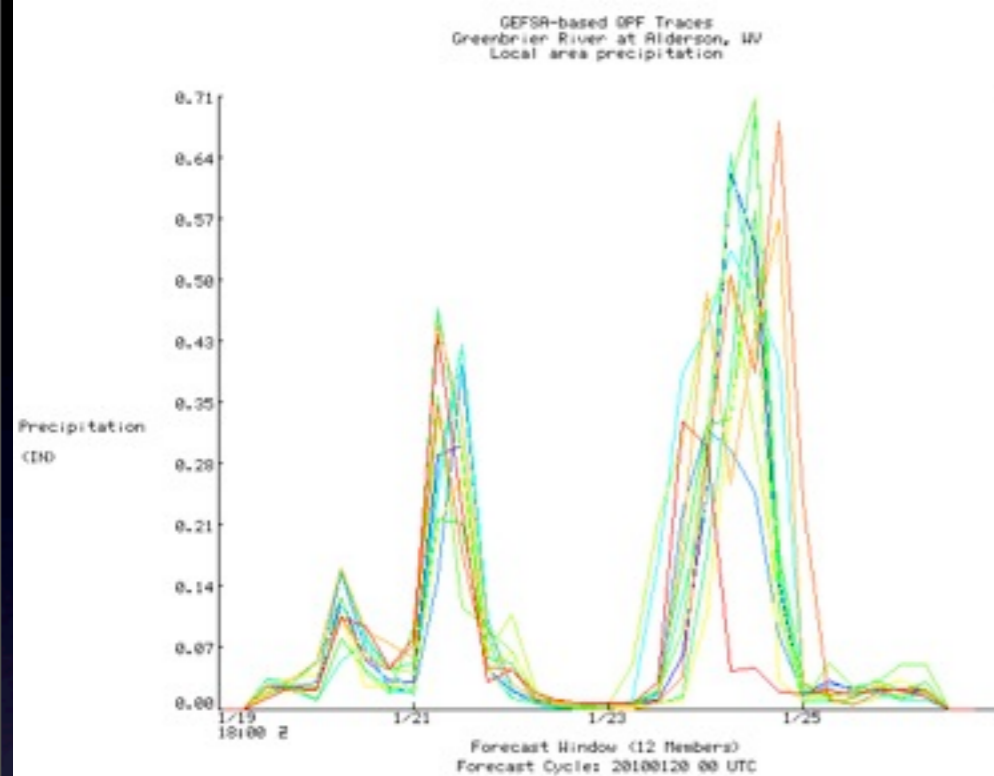
# Precipitation



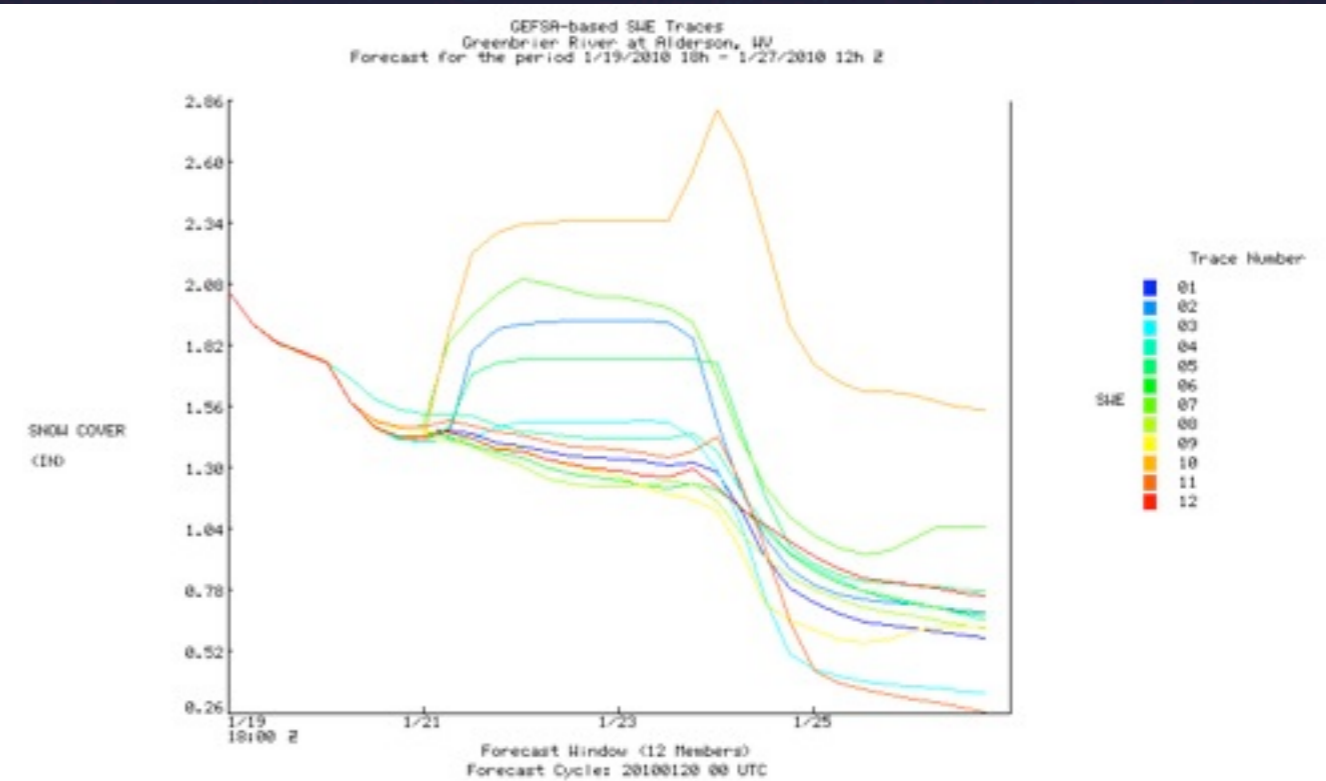
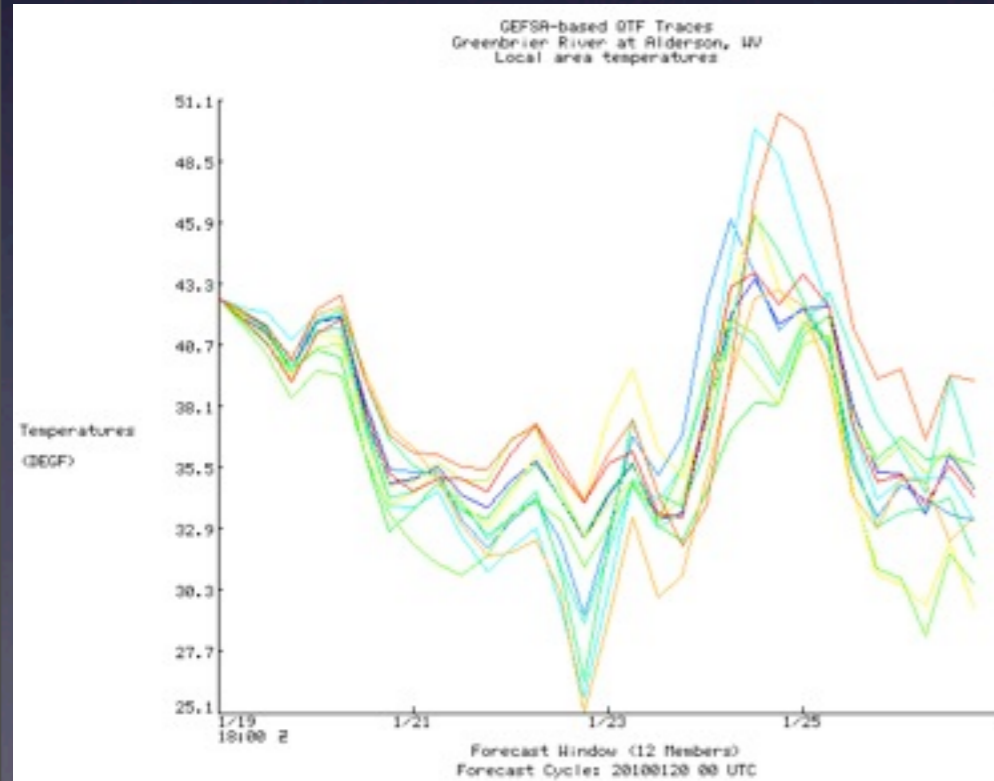
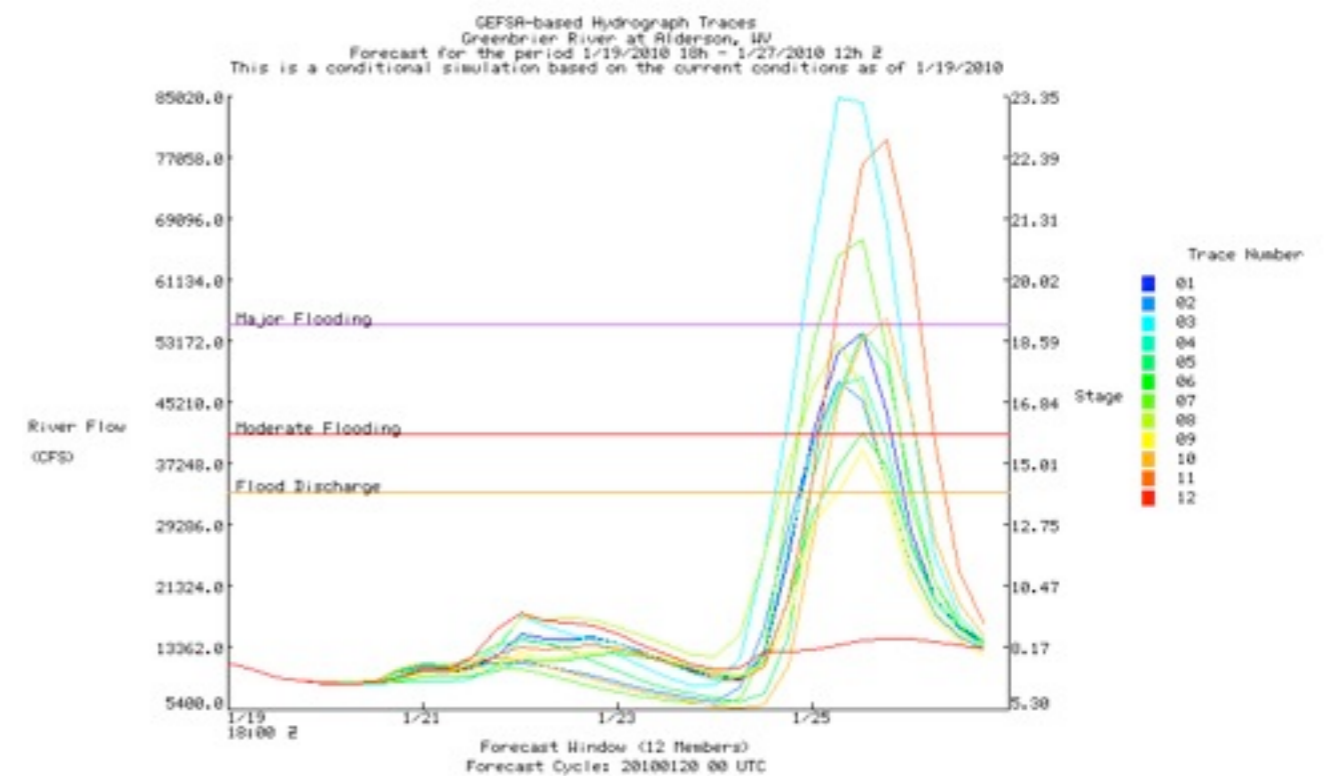
# Temperature

# Snow Water Equivalent

## Precipitation



## Streamflow

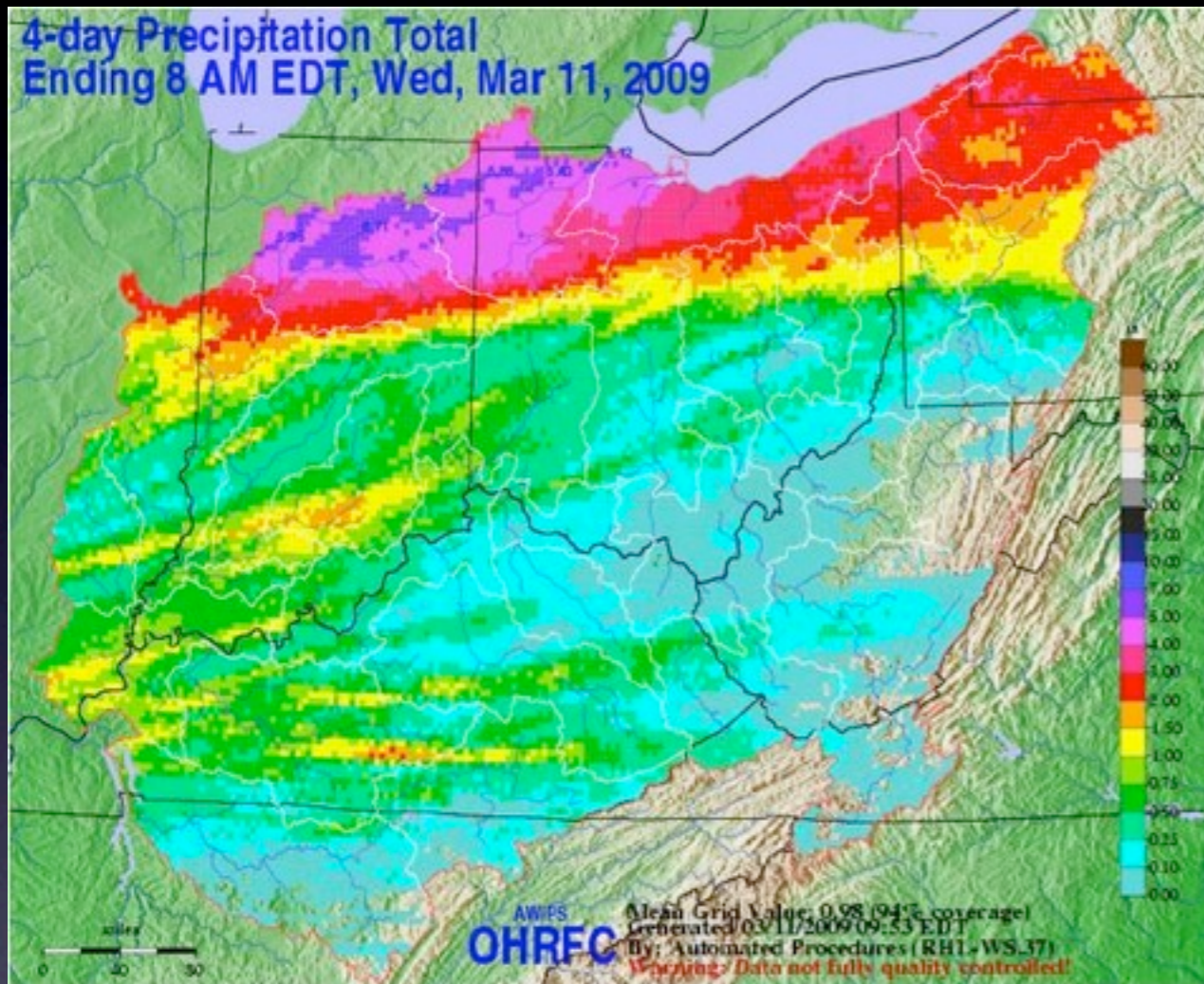


## Temperature

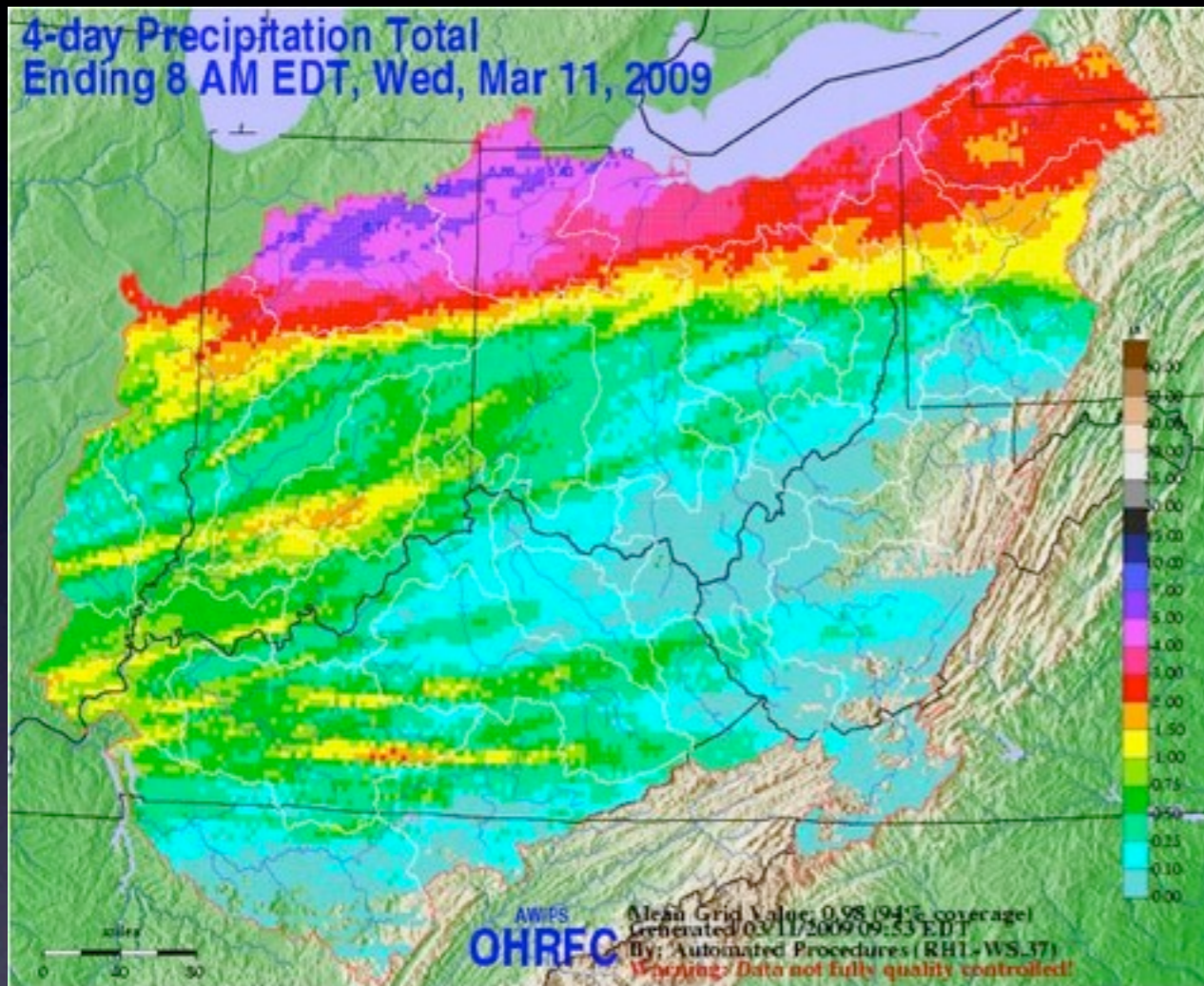
## Snow Water Equivalent

# March 6-11, 2009

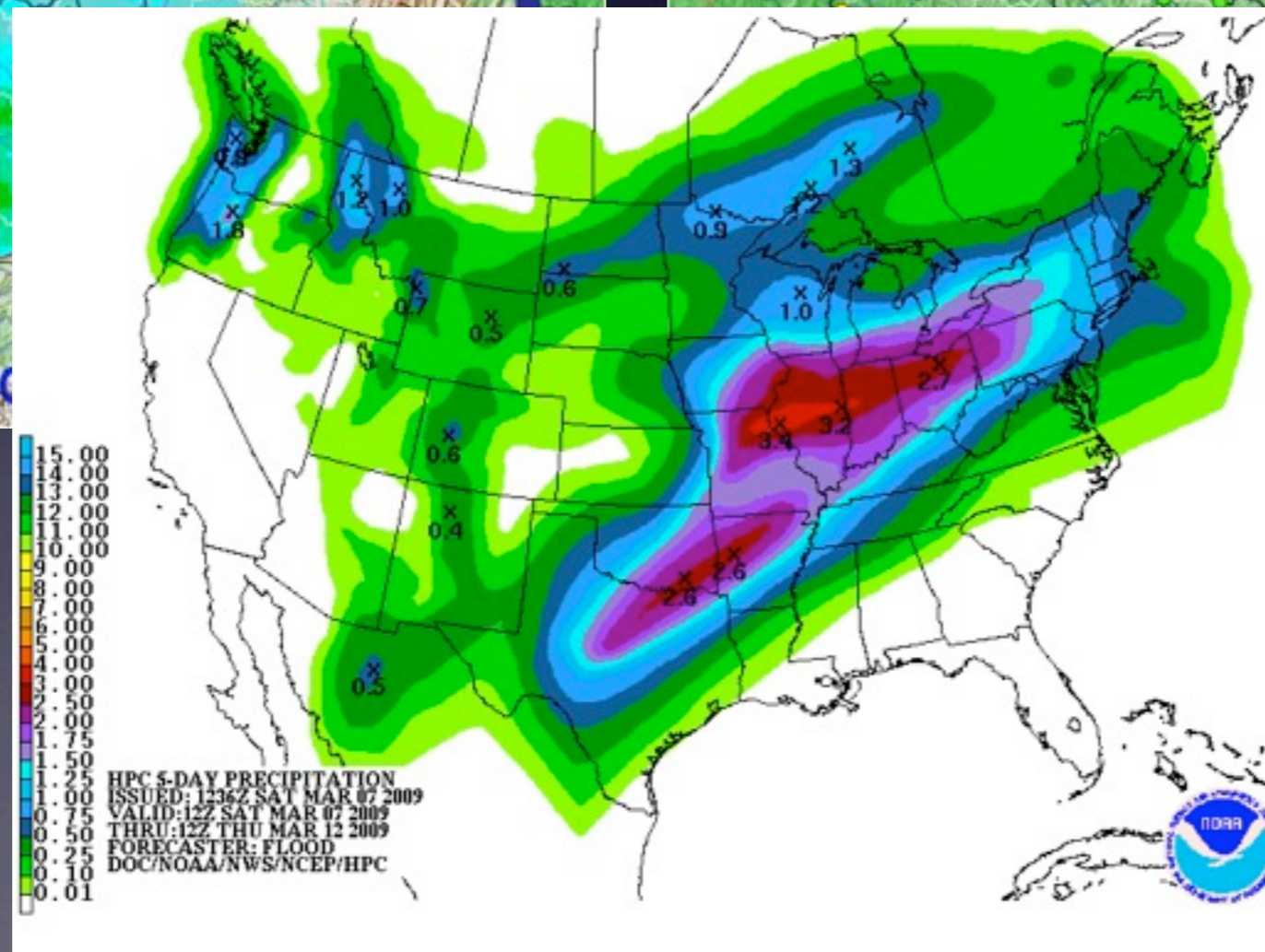
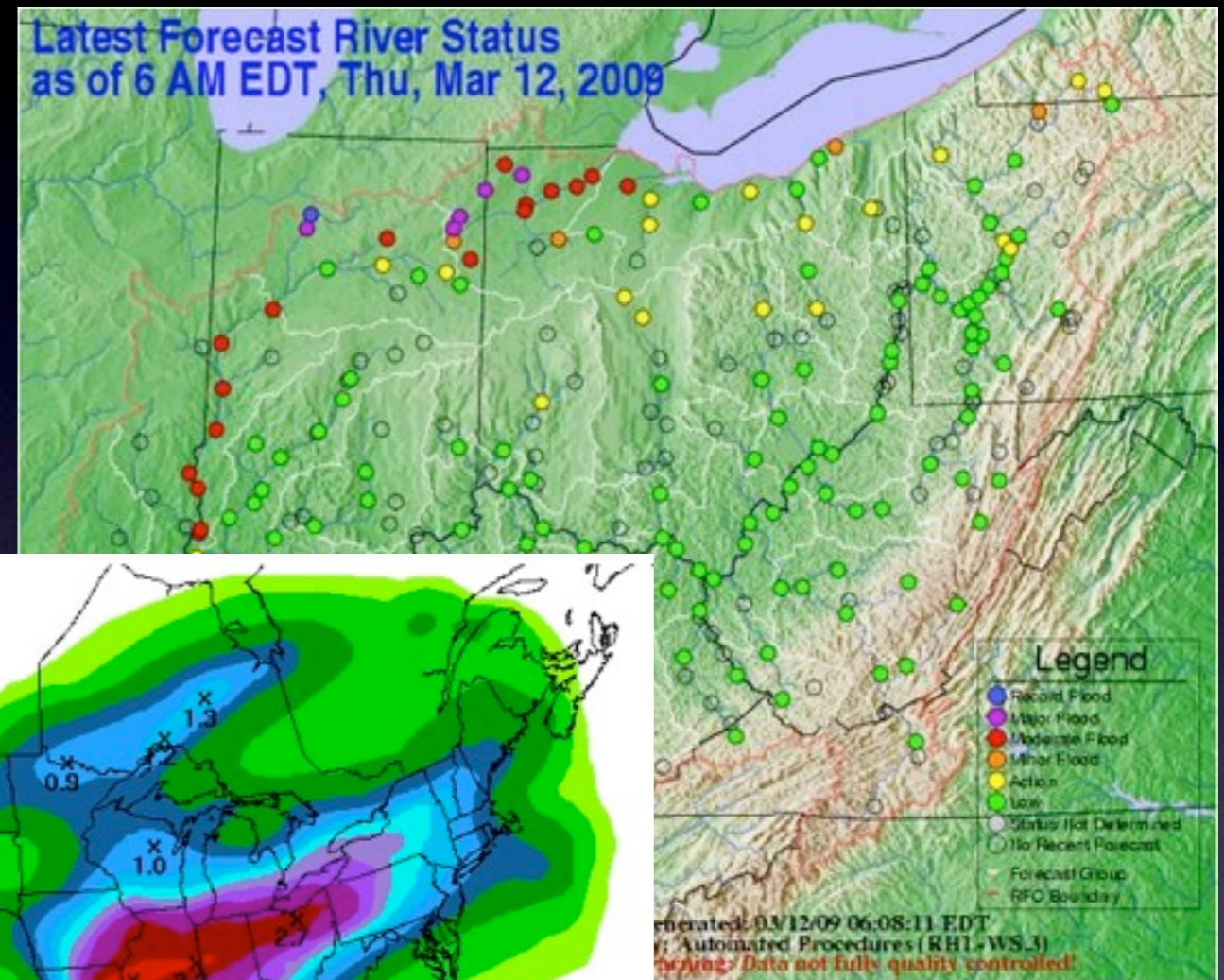
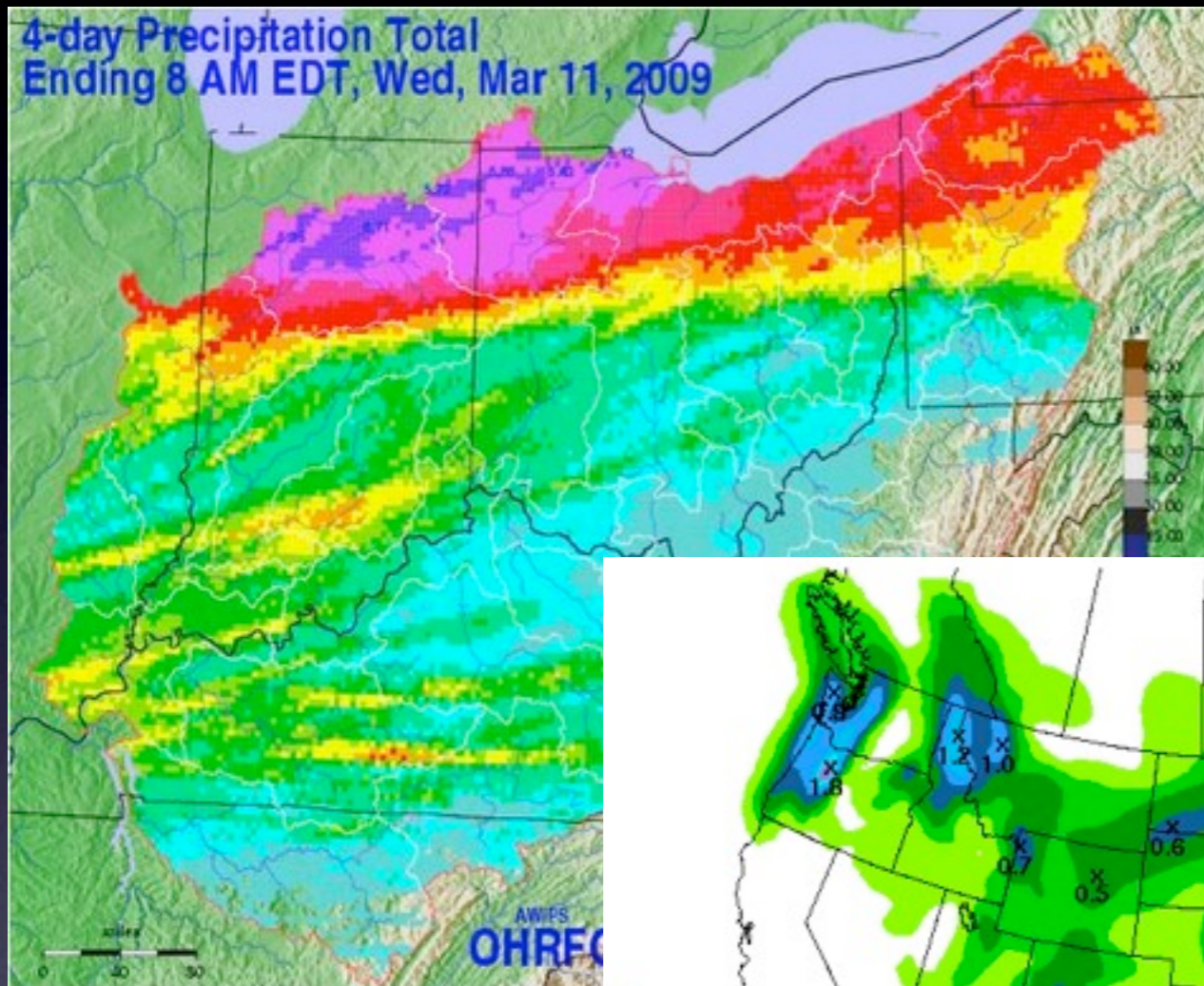
# March 6-11, 2009



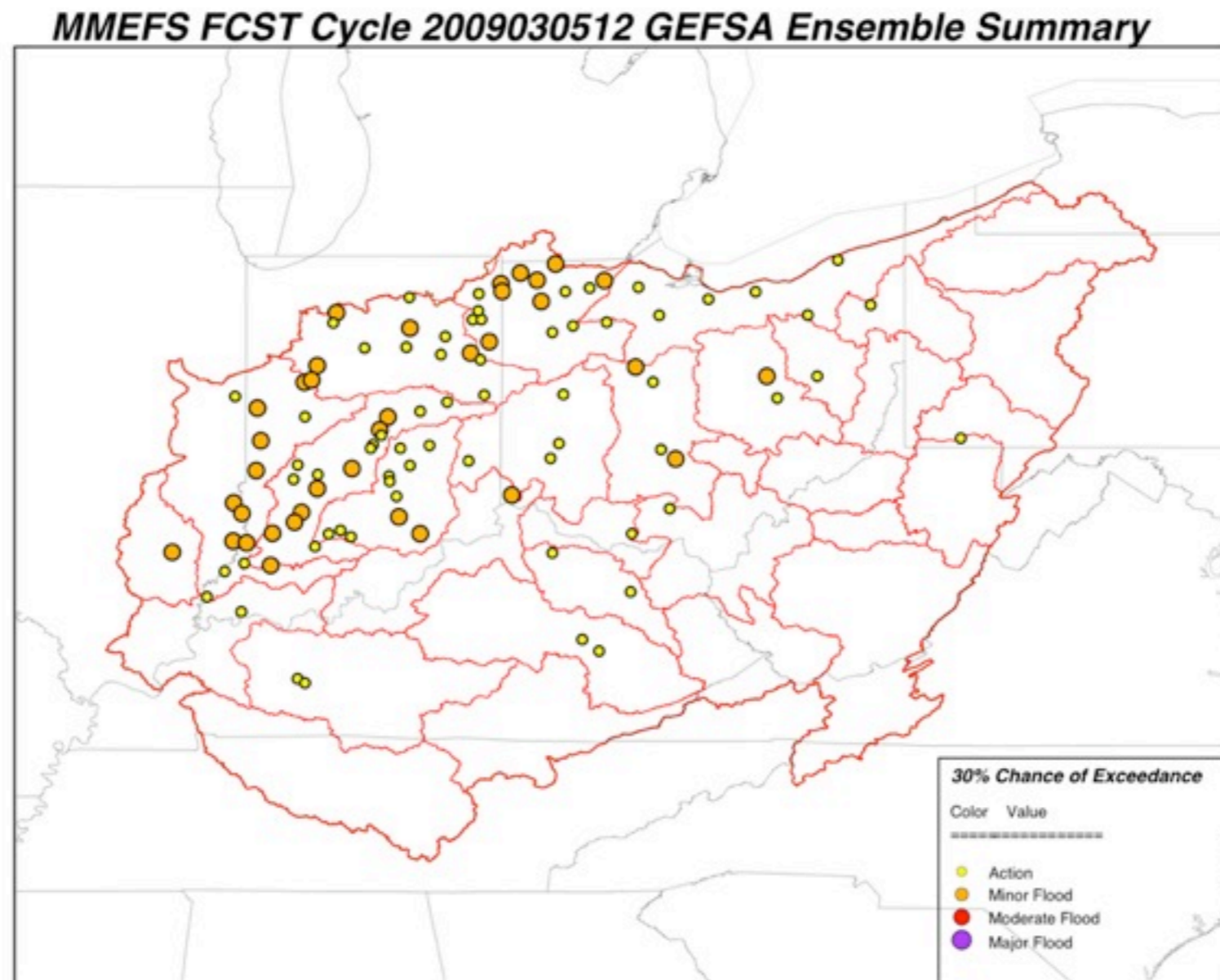
# March 6-11, 2009



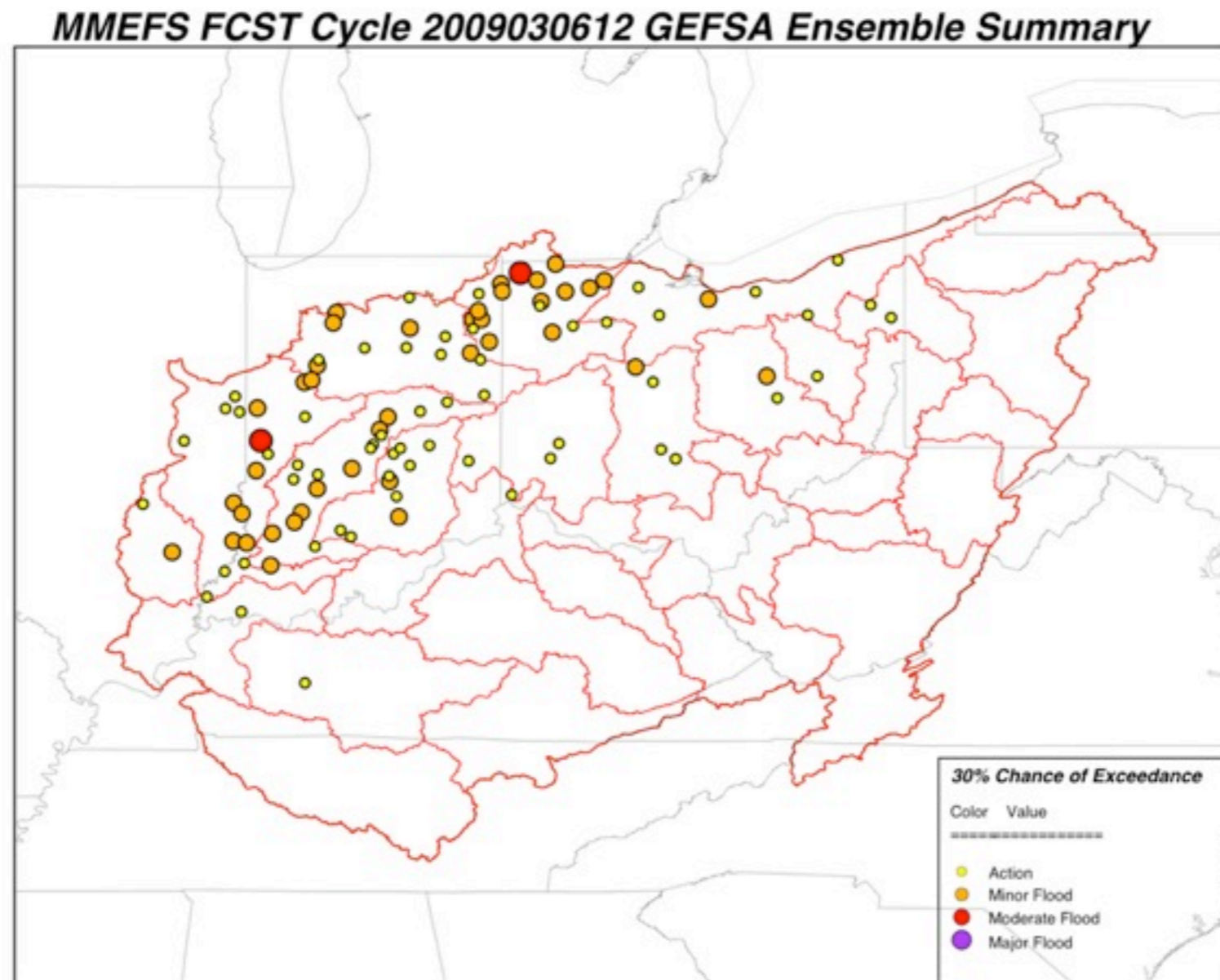
# March 6-11, 2009



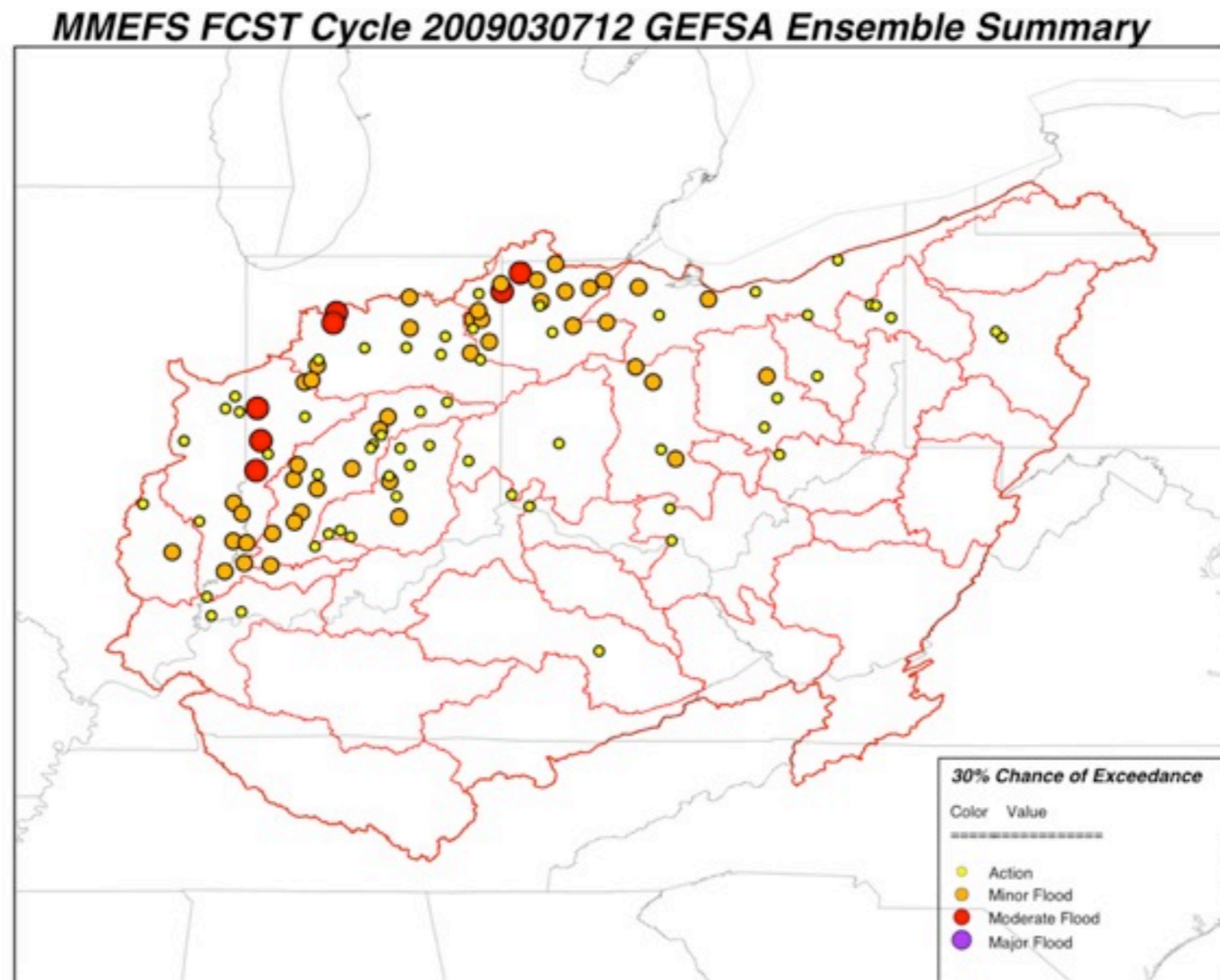
# MMEFS Summary Map



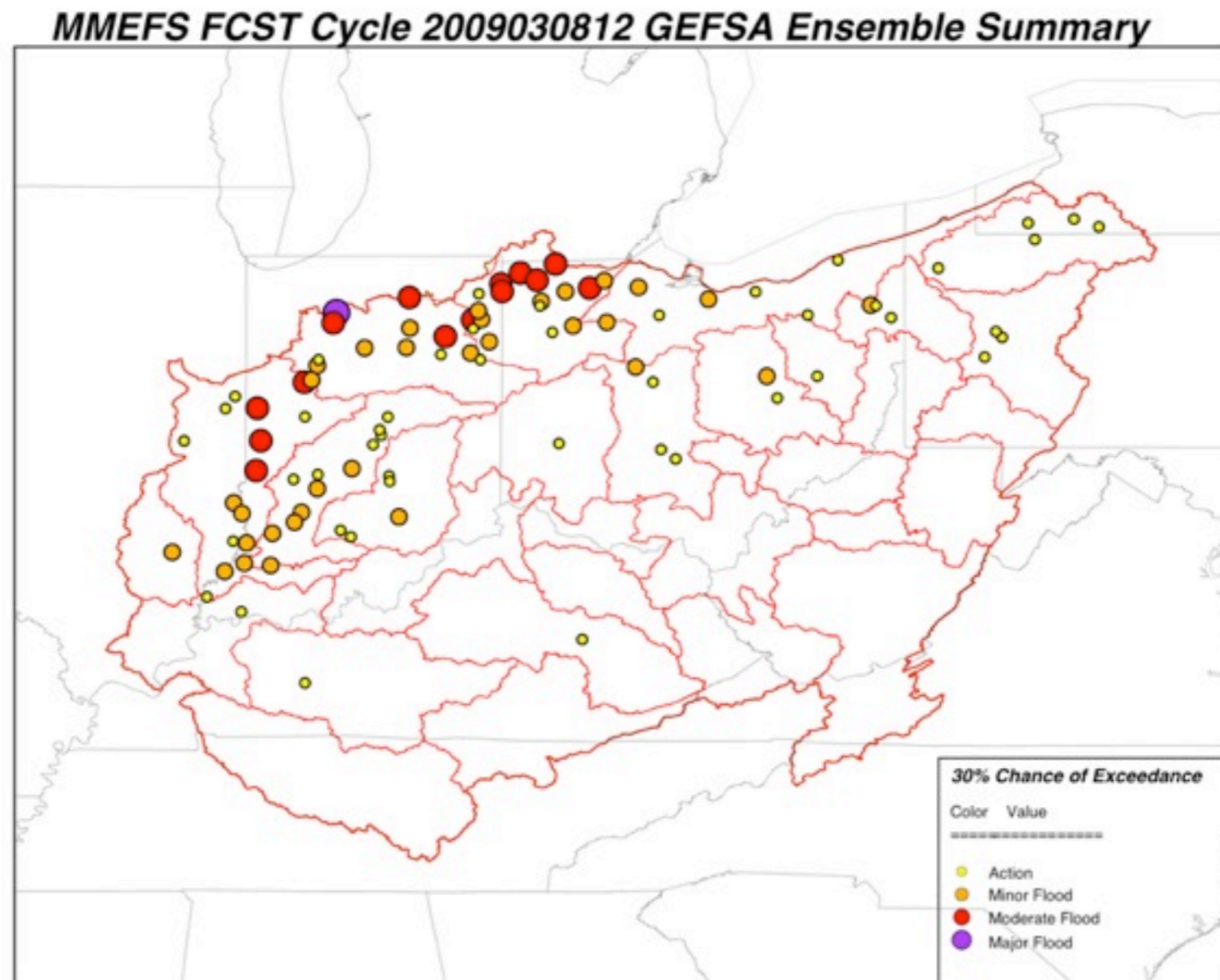
# MMEFS Summary Map



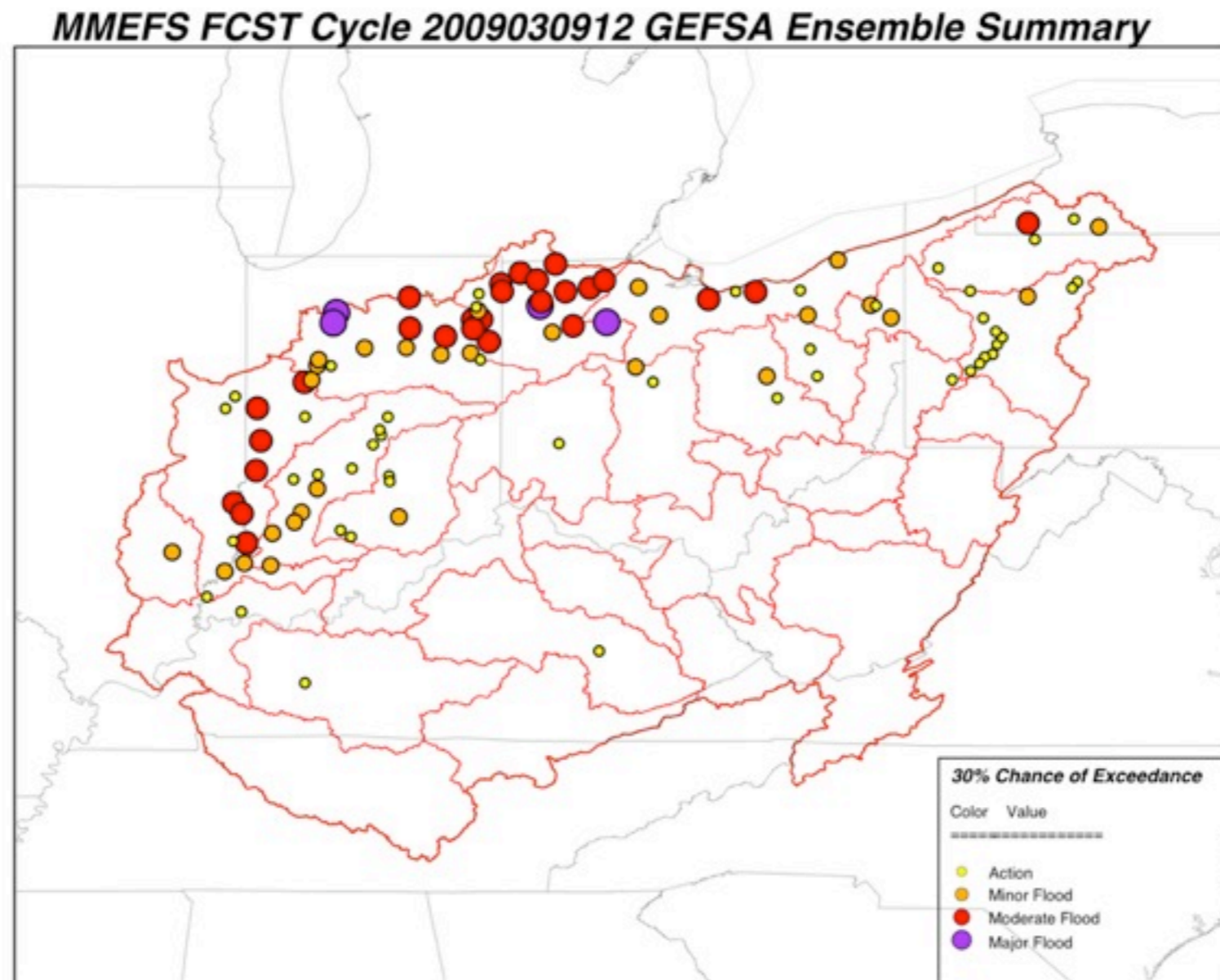
# MMEFS Summary Map



# MMEFS Summary Map

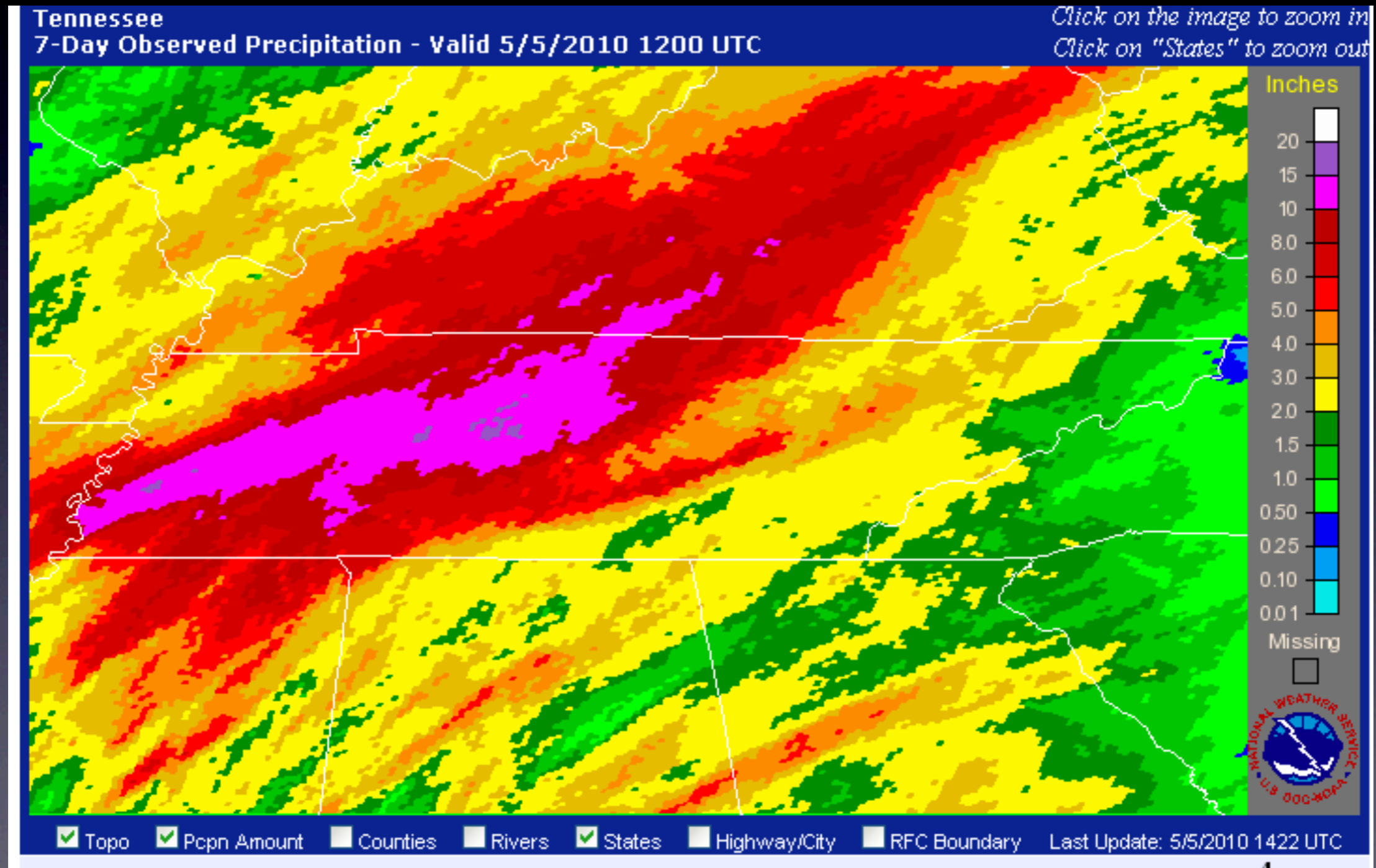


# MMEFS Summary Map



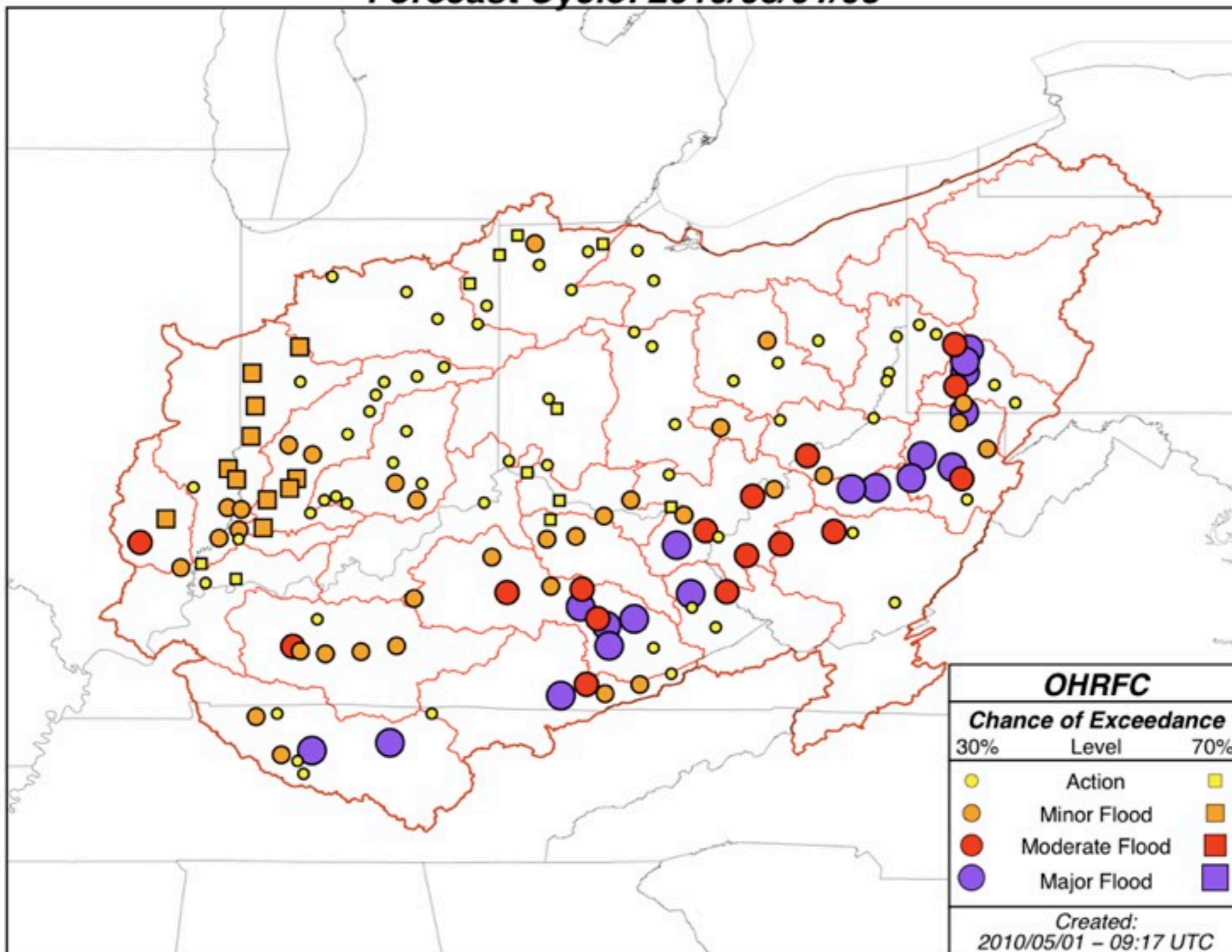
Nashville, TN  
April 30 - May 4, 2010

# 7-day precipitation ending 05 May 2010 12Z

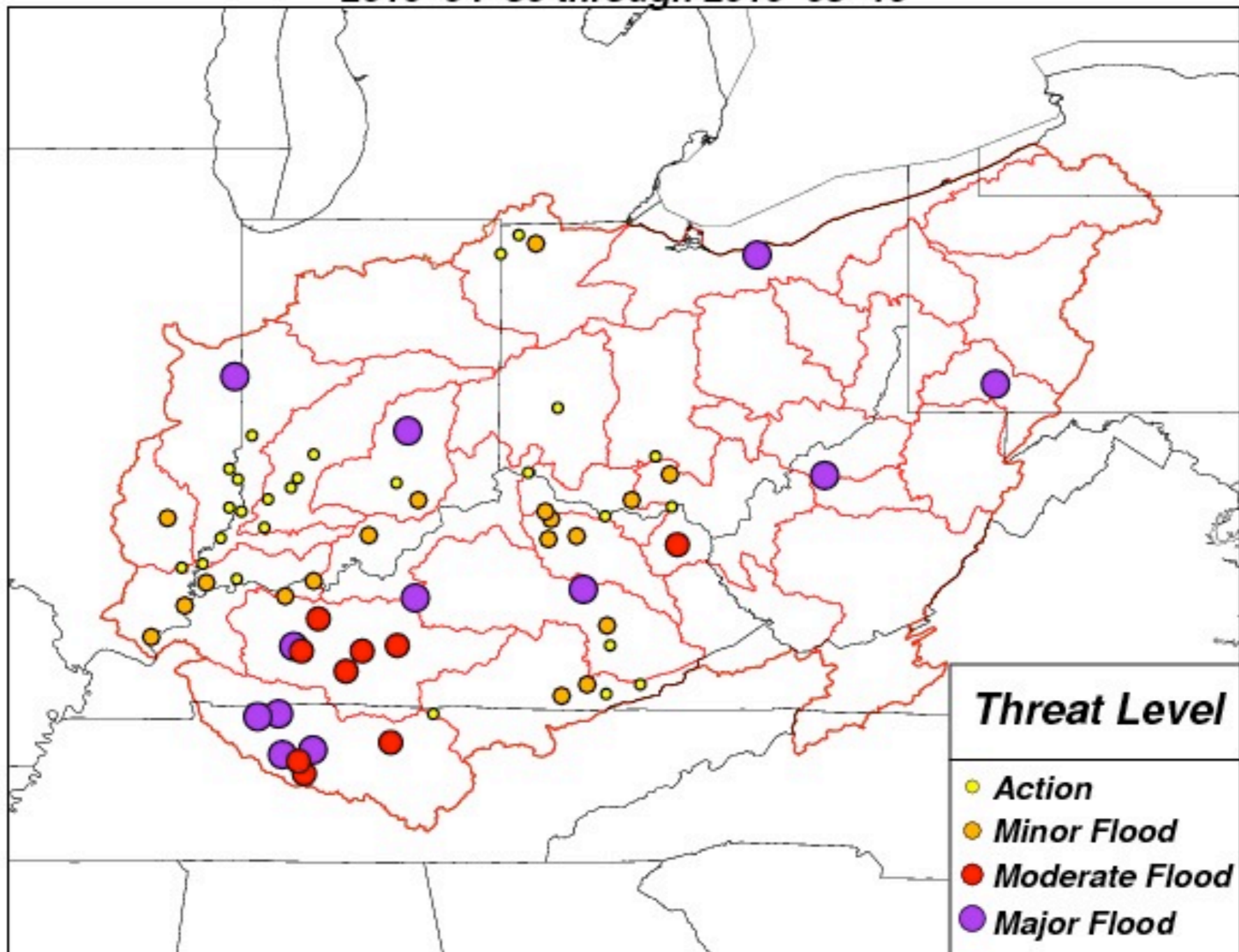




**SREF Ensemble Summary for 4/30/2010 – 5/4/2010**  
**Forecast Cycle: 2010/05/01/03**

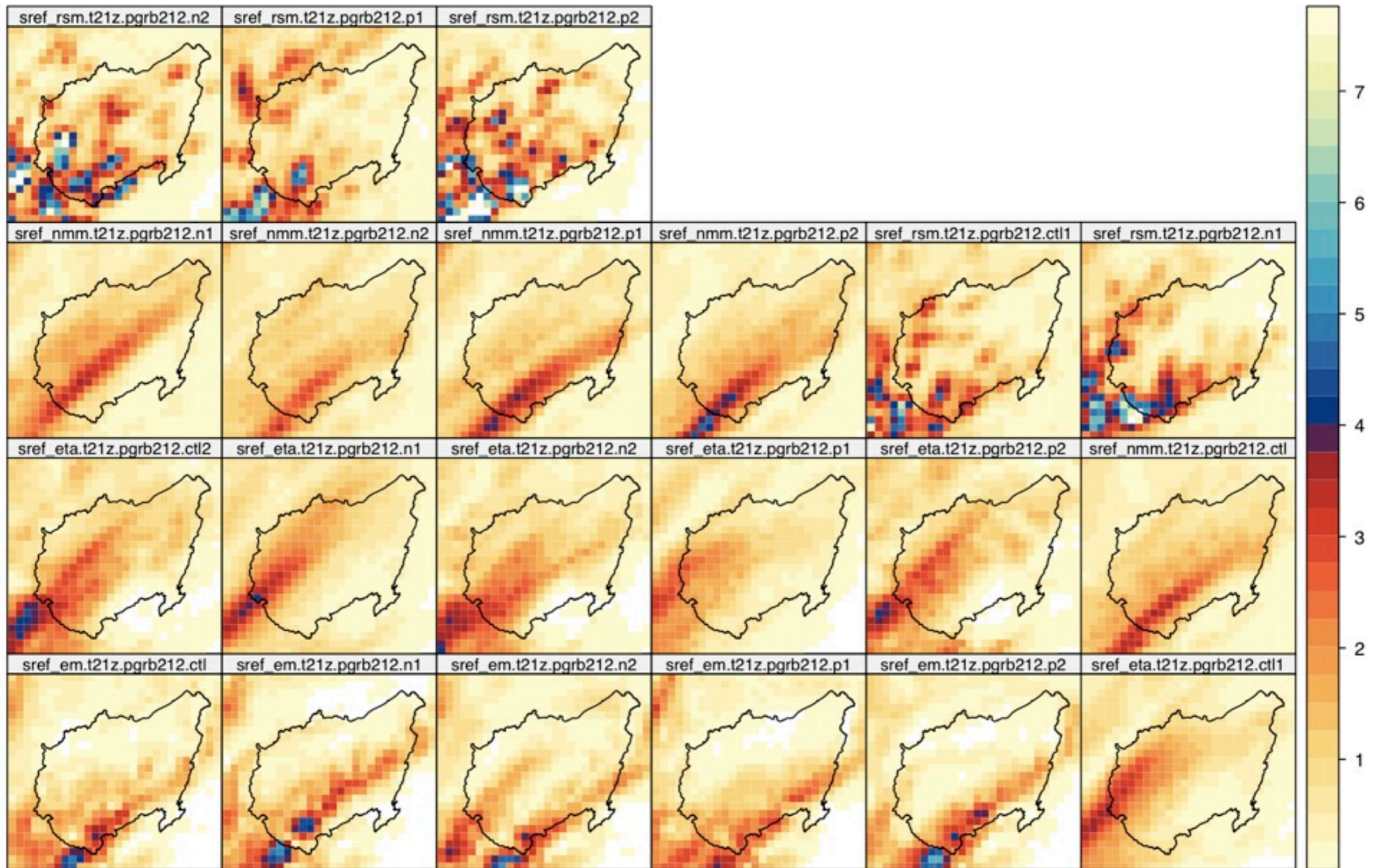


**High water observations for OHRFC  
2010-04-30 through 2010-05-10**

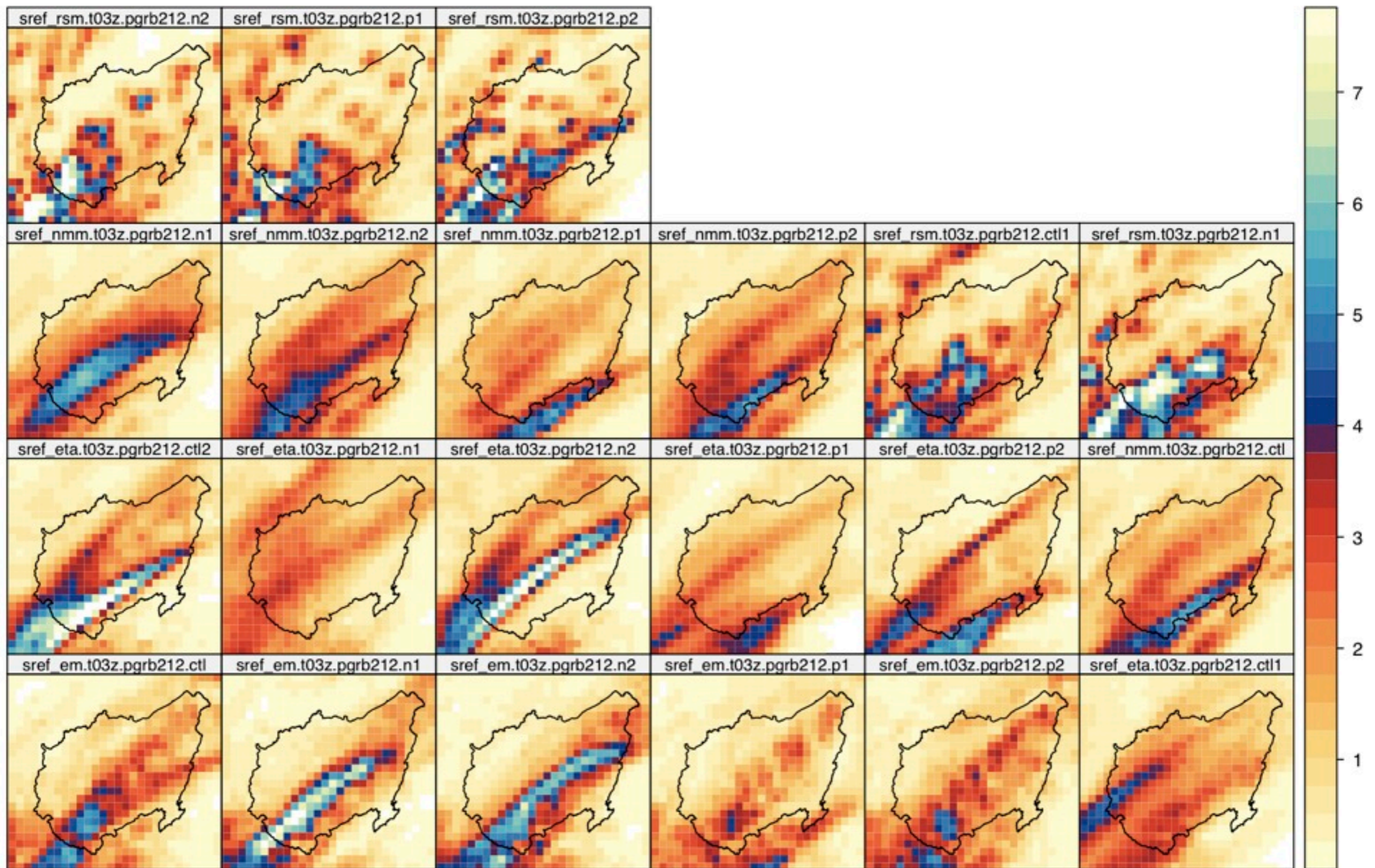




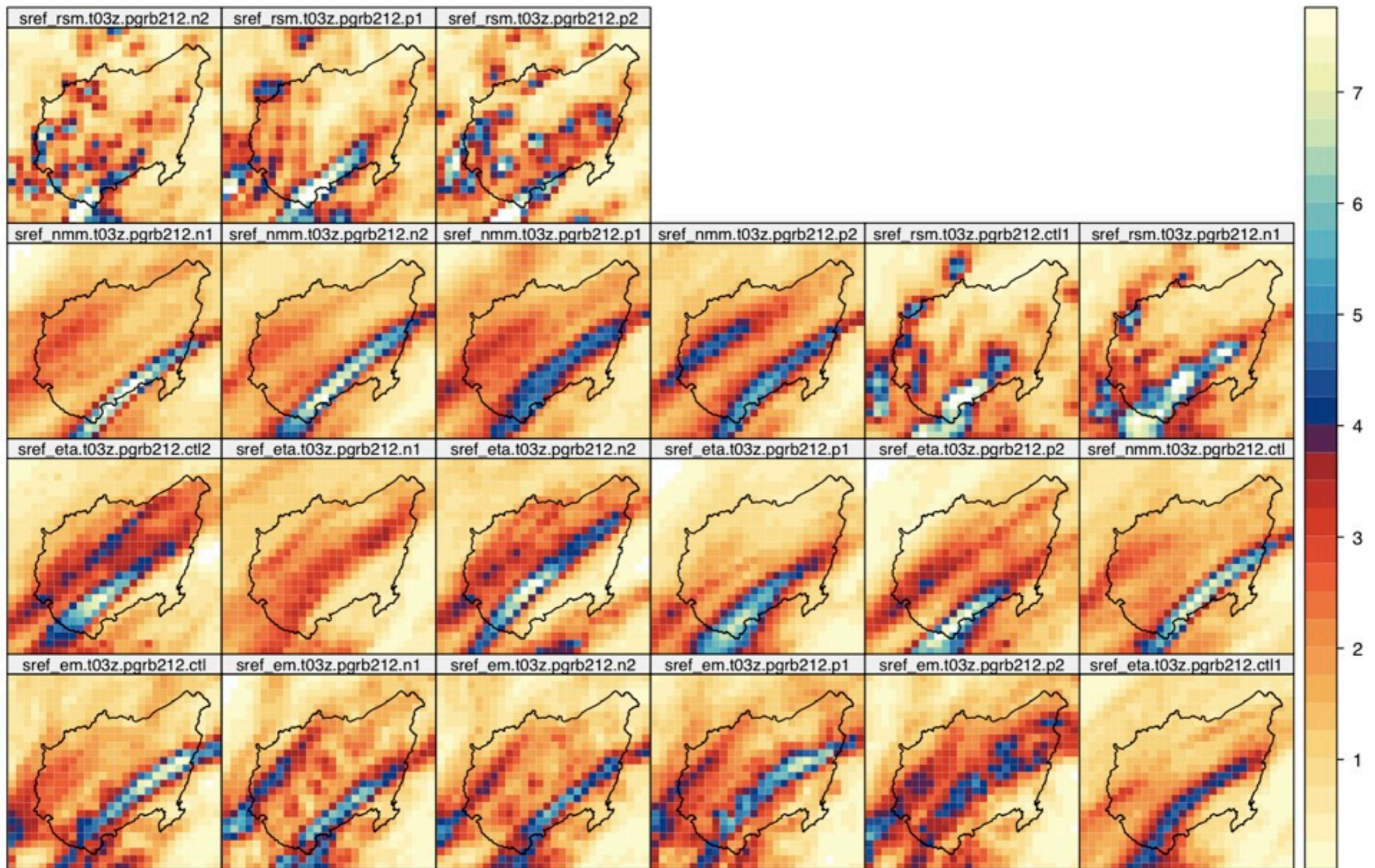
# OHRFC – SREF 87-hr Ensemble Model Precipitation: 20100428–21Z



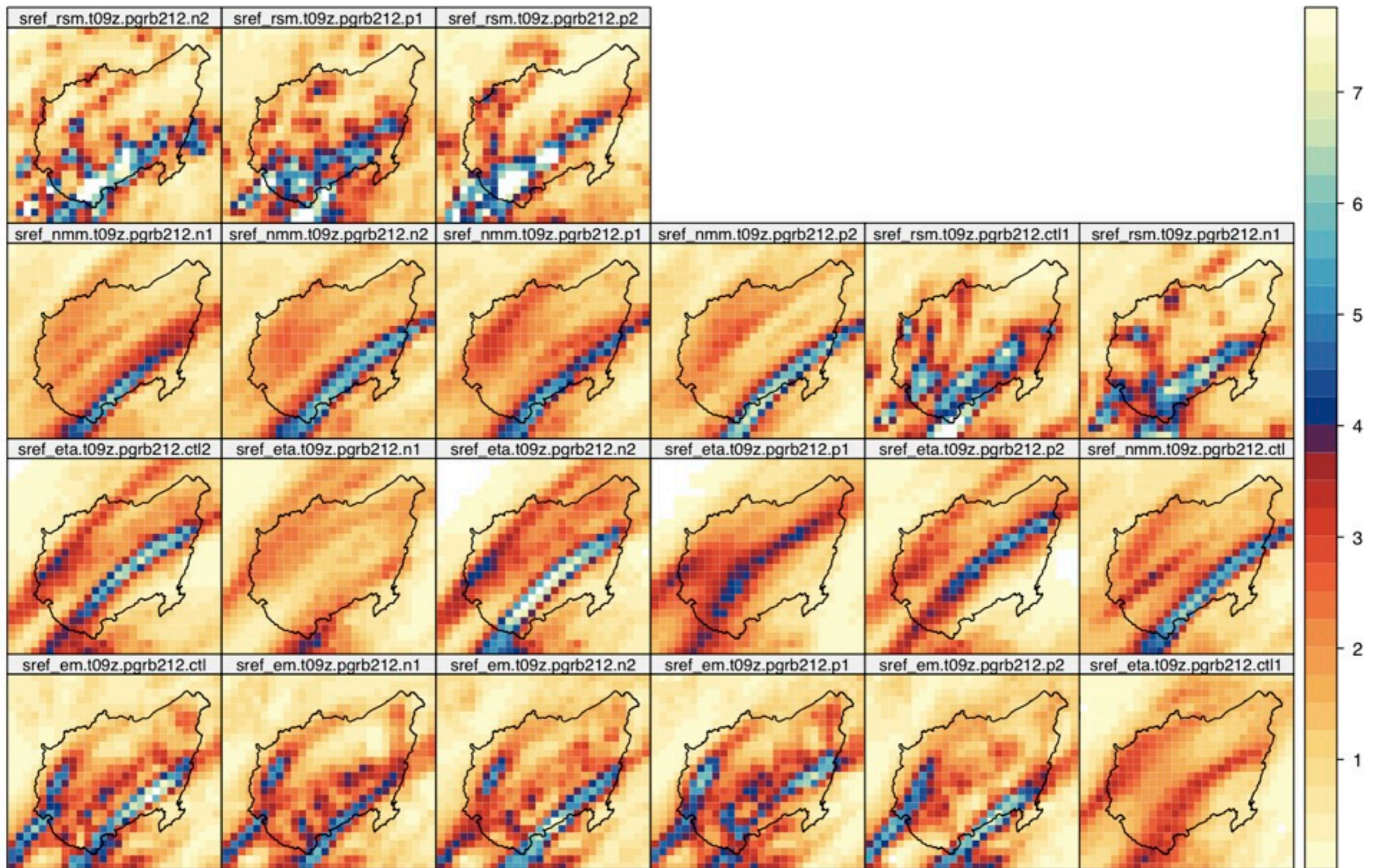
# OHRFC – SREF 87-hr Ensemble Model Precipitation: 20100430–03Z



# OHRFC – SREF 87-hr Ensemble Model Precipitation: 20100501–03Z

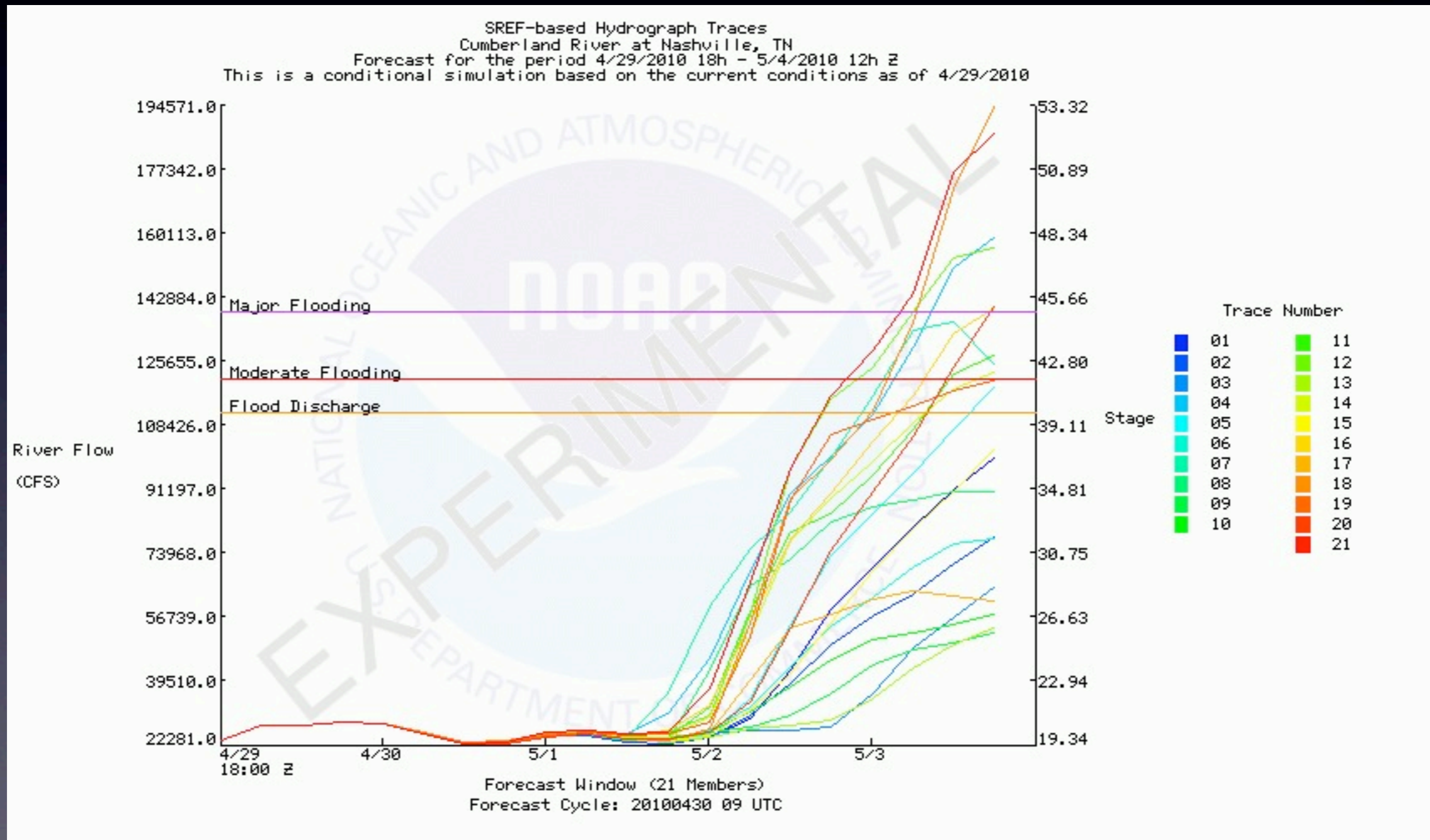


# OHRFC – SREF 87-hr Ensemble Model Precipitation: 20100501–09Z

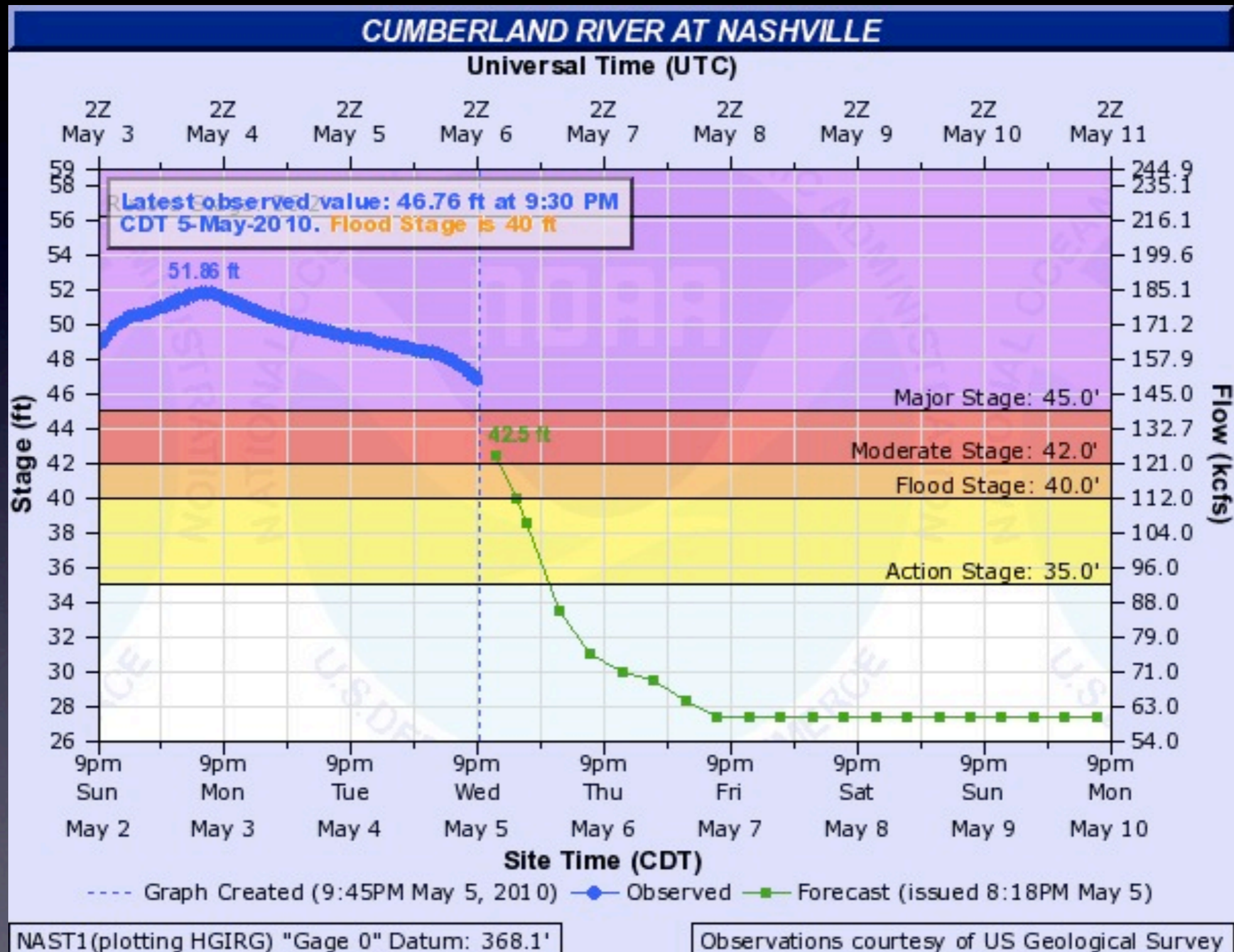


# Nashville MMEFS SREF forecast

## 04/30/2010 03Z



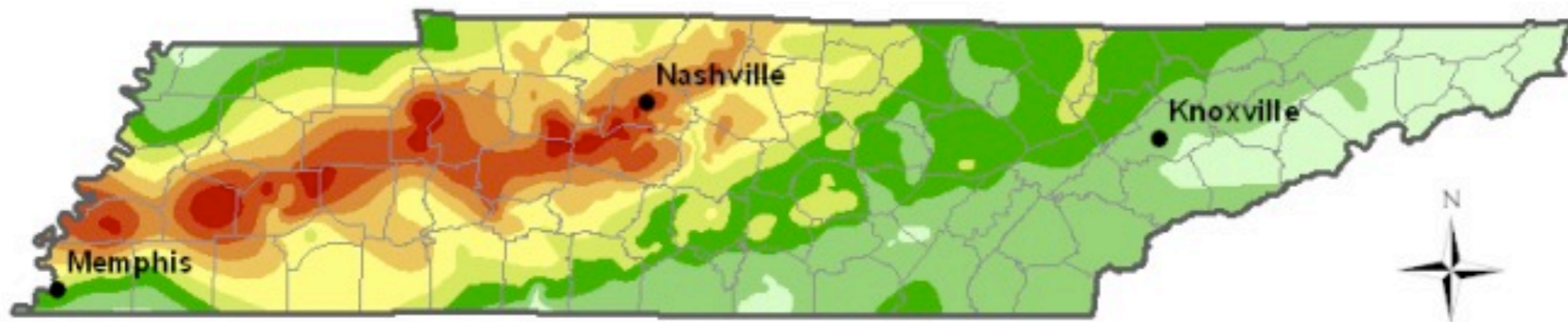
# Nashville, TN



# 48-hr precipitation ending 3-May-2010 12Z

# 48-hr precipitation ending 3-May-2010 12Z

## Weekend Rainfall Totals - May 1st & 2nd, 2010 Tennessee



Source: CoCoRaHS

0 25 50 100 150  
Miles

### Precipitation Contours

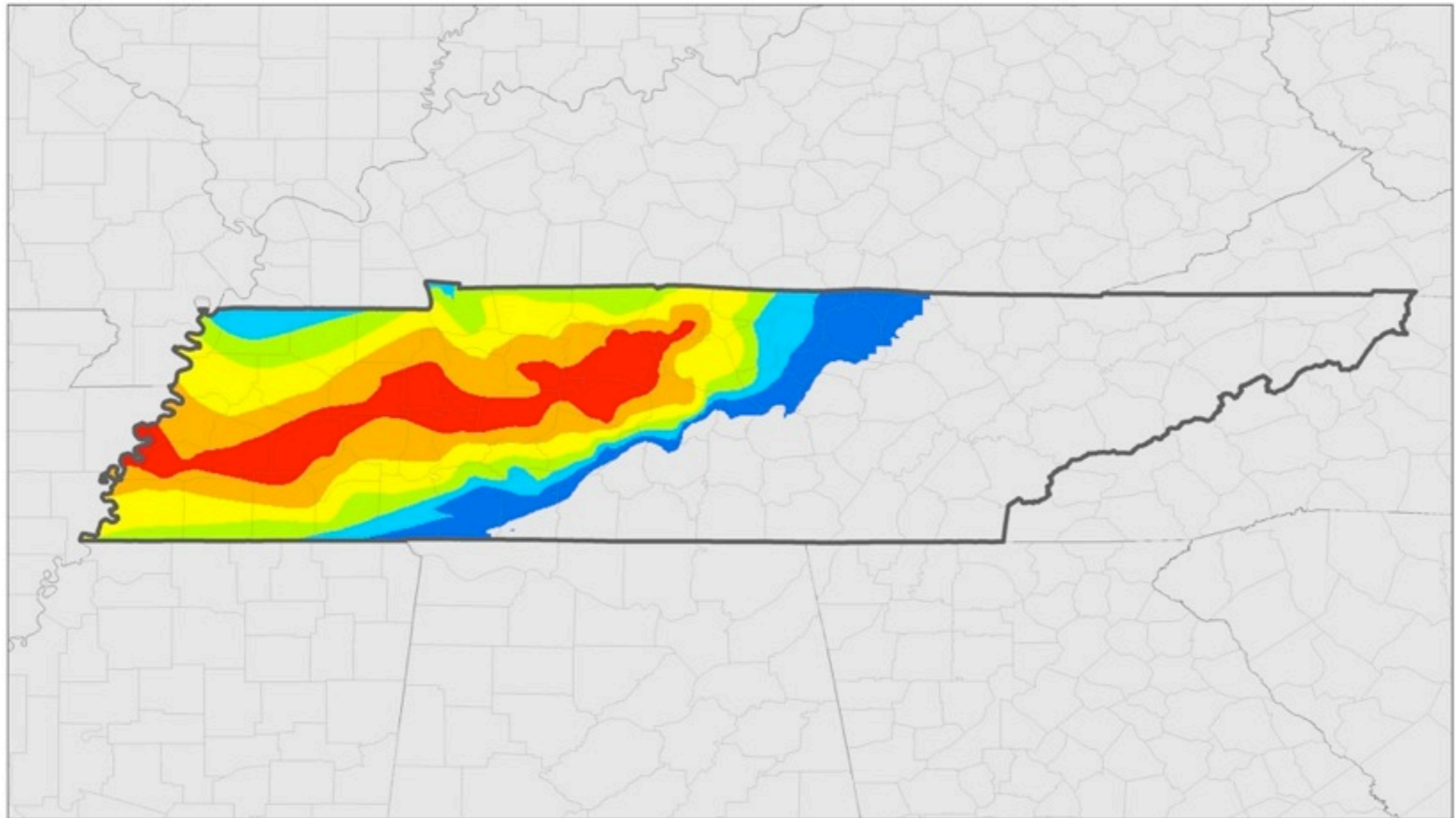
In Inches	
0.01" - 2.00"	8.01" - 10.00"
2.01" - 4.00"	10.01" - 12.00"
4.01" - 6.00"	12.01" - 14.00"
6.01" - 8.00"	14.01" - 16.00"
	16.01" - 20.00"



This map is an interpolation of actual reported values,  
but should be considered an estimation only.

Created by the National Weather Service Forecast  
Offices Nashville, Tennessee & Louisville, Kentucky

# 48-hr precipitation ending 3-May-2010 12Z



Tennessee Extreme Event of May 1-2, 2010  
Average Recurrence Intervals (ARI) for 48-Hour Duration



0 0.25 0.5 1 1.5 2  
Decimal Degrees

Created by Hydrometeorological Design Studies Center  
Office of Hydrologic Development  
National Weather Service  
National Oceanic and Atmospheric Administration

ARI (years)



# End